

HAWTHORNE



94-025 Farrington Highway • Waipahu, Hawaii 96797-2299
Phone: (808) 676-0205 • Fax: (808) 676-0264

PROJECT:

Bott Deep Well Pump Engine

BODELL CONSTRUCTION CO.
586 Fine Dr.
Salt Lake City, UT 84115
(808) 261-4110

OPERATION & MAINTENANCE MANUAL

Caterpillar C32 Industrial Engine

Serial Numbers: NST00106

October 2013

ECC-8505

Hawthorne Power Systems - Hawaii

Phone: (808) 676-0205

Fax: (808) 676-0264

Clifford Yuen, Engine Business Manager
Ed Dawe, Sales Engineer
Bob Mason, Project Engineer
Geoffrey Torres, Project Engineer
Heather Boyle, Project Manager
Pat Simonds, Project Manager
Nancy Wong, Project Administrator
Jadene Texeira, Sales / Project Coordinator
Shohan Islam, Engineering Intern



BOTT WELL ENGINE REPLACEMENT

Completion Date: October 1, 2013

BOTT WELL PUMP

PIPE & ACCESSORIES

Thermowells

Adjustable Angle

Top Load Disc Meter

ABS Standard Dry Gauges

Economy Full Port Ball Valves

Check Class 125 Bronze Screw Cap

FSC-DOM "Y" Type Strainer

Meter Flange

500XL Water Pressure Reducing Valve

Pipe Dimensions & Widths

Thermowells

for Industrial Thermometers

All dimensions are nominal. Dimensions in [] are in millimeters.

- SX9 Solar
- AX9, BX9, CX9 Adjustable Angle
- AX, BX, CX Rigid Stem
- BX Plus



THERMOWELLS

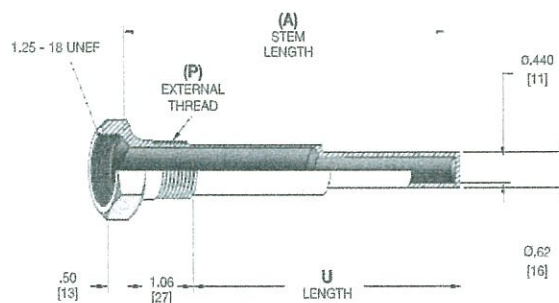
Lengths

(A) Stem Length	Standard	with Lagging Extension	
	U Length	(T)	U Length
3 1/2"	2.50 [64]	1.00 [25]	1.70 [43]
6"	5.00 [127]	2.50 [64]	2.50 [64]
8"	7.00 [178]	2.50 [64]	4.50 [114]
12"	10.50 [267]	3.00 [76]	7.50 [191]

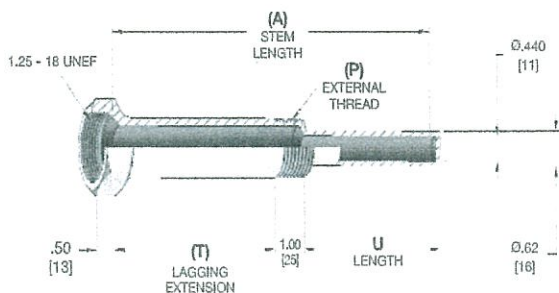
Pressure Rating (psi)

Material	Operating Temperature			
	70°F	200°F	400°F	600°F
Carbon Steel	610	550	430	350
304 Stainless Steel	630	570	460	380
316 Stainless Steel	650	600	570	500
Monel	540	480	440	400
Brass	300 psi @ 150°F, 250 @ 350°F			

Standard



with Lagging Extension



Alternative materials and accessories are also available. Please consult the Options and Accessories Section for details.

Selection of the proper thermowell is the sole responsibility of the user. Temperature and pressure limitations must be considered. Improper application may cause failure of the thermowell, resulting in possible personal injury or property damage.

HOW TO ORDER

Sample Order Number: 3-4 F 2

Thermowell Style	(P) External Thread	(A) Stem Length	(T) Lagging Extension	Material
3- Industrial	3 1/2 NPT*	F 3 1/2" Stem**	A 1" Extension (3 1/2" Stem only)	2 Brass
	4 3/4 NPT	J 6" Stem	D 2 1/2" Extension (6" and longer Stem only)†	3 Steel
	5 1 NPT	L 8" Stem	Omit if None	4 Monel
		R 12" Stem††		5 304SS
				6 316SS

* Only available with 3 1/2" stem and 1" extension.

** 3 1/2" stem Straight Shank.

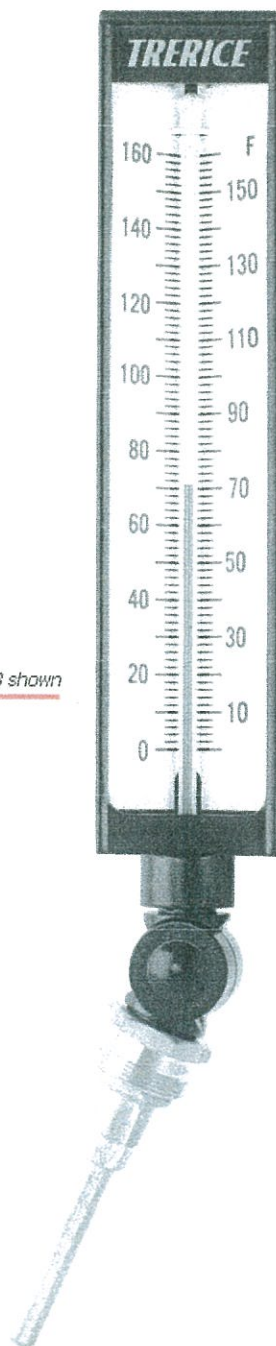
† 3" extension on 12" stem.

†† 12" stem requires 1 NPT external thread.

Adjustable Angle

7" • 9" • 12" Scale Sizes

INDUSTRIAL THERMOMETERS



BX91403 shown

- ▶ 7", 9", 12" Scale
- ▶ ± 1 Scale Division Accuracy
- ▶ Cast Aluminum Case
- ▶ Adjustable Angle Stem

Recognized globally as the Trerice "BX" Industrial Thermometer, this is an instrument of extreme accuracy and rugged dependability. Available in scale sizes of 7" (AX9), 9" (BX9), & 12" (CX9), with a durable cast aluminum case, this universally adjustable, liquid-in-glass thermometer is the most widely specified instrument of its kind.

* Optional features available:
Please consult the Options & Accessories Section for details

Thermowell

- For applications where the process media may be corrosive or contained under pressure, the use of a thermowell is required to prevent damage to the thermometer and facilitate its removal from the process. (Refer to page 152)

Specifications

Models	Scale Sizes		Adjustable Angle
AX9	7"		
BX9	9"		
CX9	12"		
Fill Type	Spirit: Blue colored, organic		
Case	Cast Aluminum, blue epoxy finish		
Stem	Aluminum, brass, 304 stainless steel or air-duct style available		
Connection	Standard: 1 1/4-18 UNEF-2A coupling nut		
	Air-Duct: Reversible mounting flange with 3 bolt holes		
Window	Ultraviolet protective acrylic on ranges to 300° F Glass on ranges over 300° F		
Tube	Lens front, magnifying type		
Scale	Aluminum, white background with black graduations and markings		
Top Plate	ABS		
Accuracy	±1 scale division		
Approximate Shipping Weight			
	AX9: 1.5 lbs [0.68 kg]		
	BX9: 1.6 lbs [0.73 kg]		
	CX9: 2.0 lbs [0.91 kg]		

HOW TO ORDER

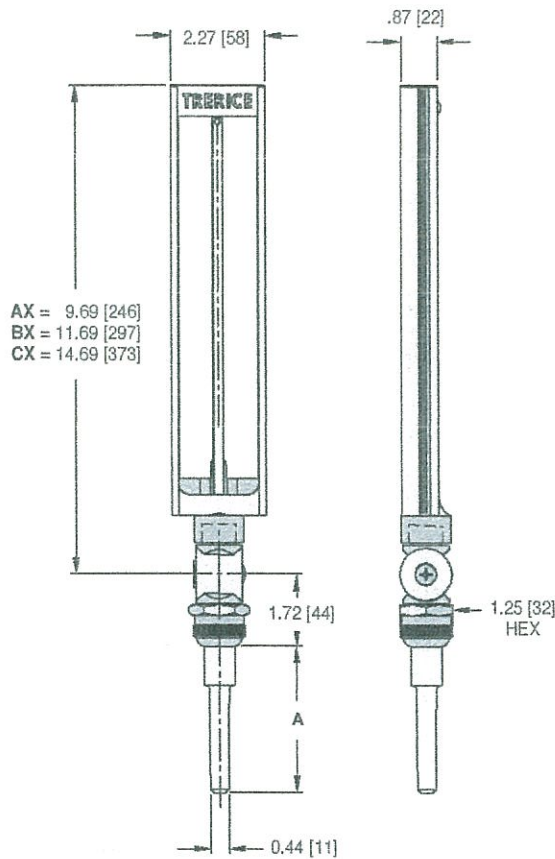
Sample Order Number: **BX9 1 403 07**

Model	Stem (Material)	Stem (Length)	Specific Range
AX9 7" Adjustable	1 Aluminum (standard)	403 31/2"	See Standard Ranges
BX9 9" Adjustable	2 Brass	406 6"	
CX9 12" Adjustable	3 304 SS	408 8"	
	9 Air-Duct (Aluminum)*	006 6" Air-Duct	

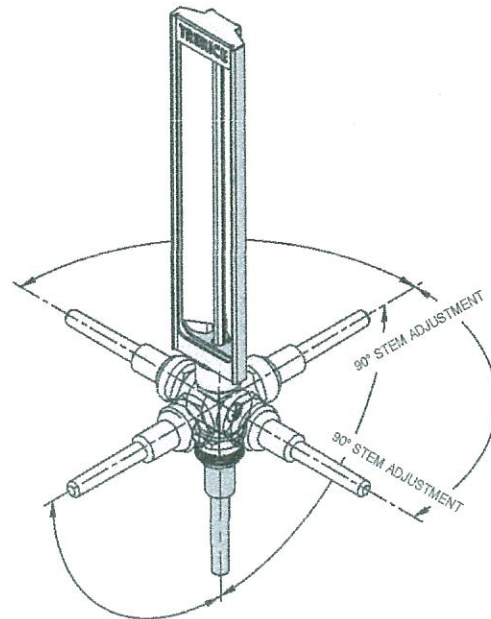
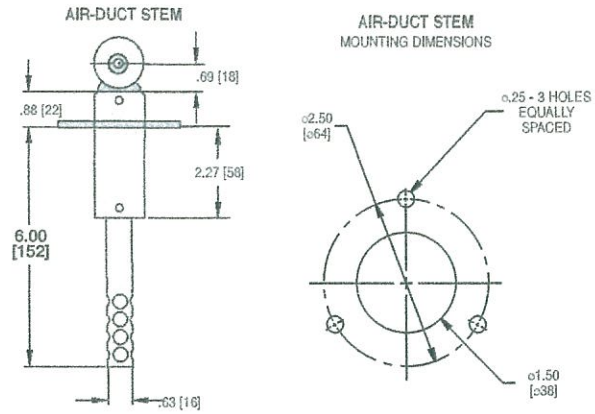
* Not for use with Thermowells

Adjustable Angle

All dimensions are nominal.
Dimensions in [] are in millimeters.



(A) Stem Length	Dimension
3 1/2"	3.50 [88.9]
6"	6.00 [152.4]
8"	8.00 [203.2]



Standard Ranges

Fahrenheit Scale		Celsius Scale		Dual Scale		Fahrenheit		Celsius	
Range Code	Range	Range Code	Range	Range Code	Range	Figure Intervals	Minor Divisions	Figure Intervals	Minor Divisions
01	-40° to 110°F	17	-40° to 40°C	41	-40° to 110°F & -40° to 40°C	10°	2°	5°	1°
02	0° to 100°F	24	-18° to 38°C	42	0° to 100°F & -18° to 38°C	5°	1°	5°	0.5°
03	30° to 130°F	25	0° to 55°C	43	30° to 130°F & 0° to 55°C	5°	1°	5°	1°
04	0° to 160°F	26	-18° to 70°C	44	0° to 160°F & -18° to 70°C	10°	2°	5°	1°
06	30° to 180°F	27	0° to 83°C	46	30° to 180°F & 0° to 83°C	10°	2°	5°	1°
07	30° to 240°F	19	0° to 115°C	47	30° to 240°F & 0° to 115°C	10°	2°	5°	1°
08	30° to 300°F	20	0° to 150°C	48	30° to 300°F & 0° to 150°C	10°	2°	10°	2°
09	50° to 400°F	28	10° to 205°C	49	50° to 400°F & 10° to 205°C	25°	5°	10°	2°
15	50° to 500°F	31	10° to 260°C	55	50° to 500°F & 10° to 260°C	25°	5°	10°	2°

Dual scale figure intervals may differ

Recordall® Cold Water Top Load Bronze Disc Meter

Size 2" (DN 50mm)

Technical Brief

DESCRIPTION

Badger Meter offers the Recordall Disc meter in Cast Bronze and a Low Lead Alloy. The Low Lead Alloy (Trade Designation: M170 LL) version complies with NSF/ANSI Standard 61 and carries the NSF-61 Mark on the housing. All components of the Low Lead Alloy meter, i.e., disc, chamber, housing, seals, etc., comprise the certified system.

APPLICATIONS: For use in measurement of potable cold water in residential, commercial and industrial services where flow is in one direction only.

OPERATION: Water flows through the meter's strainer and into the measuring chamber where it causes the disc to rotate. The disc, which moves freely, rotates on its own ball, guided by a thrust roller. A drive magnet transmits the motion of the disc to a follower magnet located within the permanently-sealed register. The follower magnet is connected to the register gear train. The gear train reduces the disc rotations into volume totalization units displayed on the register dial face.

OPERATING PERFORMANCE: The Badger Recordall Disc meters meet or exceed registration accuracy for the low flow rates (95%), normal operating flow rates ($100 \pm 1.5\%$), and maximum continuous operation flow rates as specifically stated by AWWA Standard C700.

CONSTRUCTION: Badger Recordall Disc meter construction, which complies with ANSI/AWWA standard C700, consists of three basic components: bronze meter housing, measuring chamber, and permanently, sealed register. A corrosion-resistant thermoplastic material is used for the measuring chamber.

To simplify maintenance, the register, measuring chamber, and strainer can be replaced without removing the meter housing from the installation. No change gears are required for accuracy calibration. Interchangeability of parts among like-sized meters also minimizes spare parts inventory investment. The built-in strainer has an effective straining area of twice the inlet size.

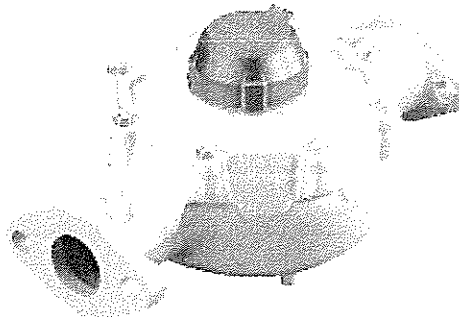
MAGNETIC DRIVE: Direct magnetic drive, through the use of high-strength magnets, provides positive, reliable and dependable register coupling for straight-reading, remote or automatic meter reading options.

SEALED REGISTER: The standard register consists of a straight-reading, odometer-type totalization display, 360° test circle with center sweep hand and flow finder to detect leaks. Register gearing consists of self-lubricating thermoplastic gears to minimize friction and provides long life. Permanently sealed; dirt, moisture, tampering and lens fogging problems are eliminated. Multi-position register simplifies meter installation and reading. Generator-type remote reading and automatic meter reading systems are available for all Recordall Disc meters. All reading options are removable from the meter without disrupting water service.

TAMPER-PROOF FEATURES: Customer removal of the register to obtain free water can be prevented when the optional tamper detection seal wire screw/or Torx® tamper seal resistant screw is added to the meter. Both can be installed at the meter site or at the factory.

MAINTENANCE: Badger Recordall Disc meters are designed and manufactured to provide long-term service with minimal maintenance. When maintenance is required, it can be performed easily either at the meter installation or at any other convenient location. As an alternative to repair by the utility, Badger offers various maintenance and meter component exchange programs to fit the needs of the utility.

CONNECTIONS: Tailpieces/Flanges for installations of meters on various pipe types and sizes, including misaligned pipes, are available as an option.



Model 170 shown with optional 1" Test Plug

SPECIFICATIONS

Typical Operating Range (100% ± 1.5%)	2 1/2 - 170 GPM (.57 to 39 m³/hr)
Low Flow (Min. 95%)	1 1/2 GPM (.34 m³/hr)
Maximum Continuous Operation	100 GPM (23 m³/hr)
Pressure Loss at Maximum Continuous Operation	3.3 PSI at 100 GPM (.23 bar at 23 m³/hr)
Maximum Operating Temperature	80°F (26°C)
Maximum Operating Pressure	150 PSI (10 bar)
Measuring Element	Nutating disc, positive displacement
Register Type	Straight reading, permanently sealed magnetic drive standard. Remote reading or Automatic Meter Reading units optional.
Registration	100 Gallons, 10 Cubic Feet, 1 m³
Register Capacity	100,000,000 Gallons, 10,000,000 Cubic Feet, 1,000,000 m³. 6 odometer wheels.
Meter Connections	2" AWWA two bolt elliptical flange, drilled, or 2" - 11 1/2 NPT internal pipe threads.
Optional Test Plug	1" NPT test plug (TP) available on elliptical long and short versions.

MATERIALS

Meter Housing	Cast Bronze, Low Lead Alloy
Housing Top Plates	Bronze, Low Lead Alloy
Measuring Chamber	Thermoplastic
Disc	Thermoplastic
Trim	Stainless Steel/Bronze
Strainer	Thermoplastic
Disc Spindle	Stainless Steel
Magnet	Ceramic
Magnet Spindle	Stainless Steel
Register Lid and Box	Thermoplastic or Bronze
Generator Housing	Thermoplastic



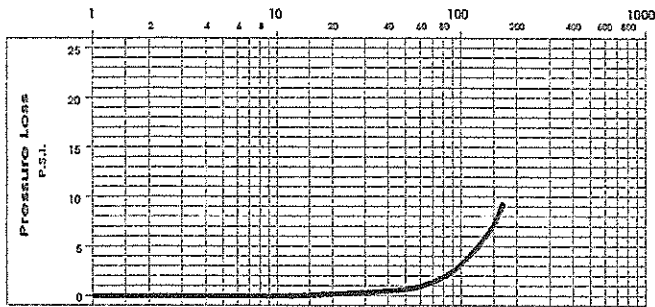
BadgerMeter, Inc.

RD-T-2

9-06

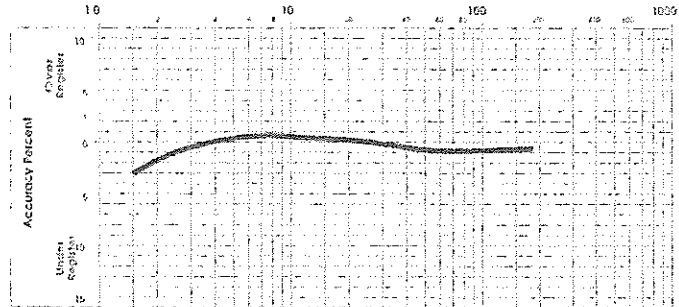
PRESSURE LOSS CHART

Rate of Flow, in Gallons per Minute



ACCURACY CHART

Rate of Flow, in Gallons per Minute



METER SIZE	METER MODEL	A LAYING LENGTH	B HEIGHT REG./RTR	C HEIGHT GEN.	D CENTERLINE BASE	WIDTH	APPROX. SHIPPING WEIGHT
2" (50mm)	170 EL, Hex. 170 EL, TP	15 1/4" (387mm)	8" (203mm)	9 3/8" (238mm)	2 7/8" (73mm)	9 1/2" (241mm)	30 lb. (13.6kg)
2" (50mm)	170 ELL, 170 ELL, TP	17" (432mm)	8" (203mm)	9 3/8" (238mm)	2 7/8" (73mm)	9 1/2" (241mm)	30 lb. (13.6kg)

EL = Elliptical

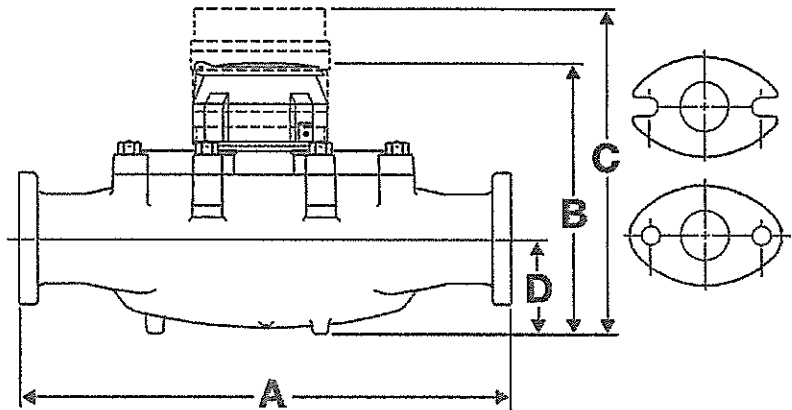
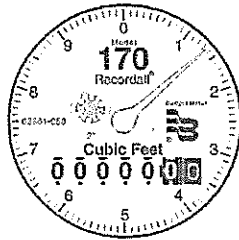
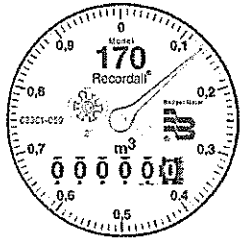
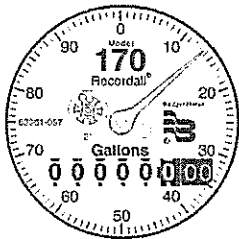
ELL = Elliptical Long

Hex = Hexagon, 2" - 11 1/2 NPT Thread

TP=Test Plug 1"

Sweep Hand Registration

MODEL	GALLON	CU.FT.	CU. METER
M170	100	10	1



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Please see our website at
www.badgermeter.com
for specific contacts.

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BadgerMeter, Inc.

P.O. Box 245036, Milwaukee, WI 53224-9536
(800) 876-3837 / Fax: (888) 371-5982

www.badgermeter.com

ABS Standard Dry Gauges

Features:

ASME B40.1, Grade B ($\pm 3-2-3\%$ accuracy)
 ABS plastic case
 c-shaped bronze safety bourdon tube (600 PSI and lower)
 helical wound bronze safety bourdon tube (1000 PSI and higher)

polycarbonate crystal
 black aluminum pointer
 PowerFlex™ movement with polyester segment, designed to resist the effects of shock, vibration and pulsation.
 ambient temperature range of -40°F to 150°F

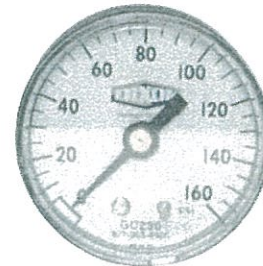
Center Back Mount

1½" face
 1/8" center back mount

PSI	Fig. Inter.	Minor Grad.	Part #	Price/E
0-30	5	.5	GC605	\$16.70
0-60	5	1	GC610	16.70
0-100	10	2	GC615	16.70
0-160	20	5	GC620	16.70
0-200	20	5	GC625	16.70

2" face
 1/4" center back mount

PSI	Fig. Inter.	Minor Grad.	Part #	Price/E
0-15	1	.5	GC200	\$22.20
0-30	5	.5	GC215	20.70
0-60	5	1	GC220	20.70
0-100	10	2	GC225	20.70
0-160	20	5	GC230	20.70
0-200	20	5	GC235	20.70
0-300	30	5	GC240	20.70



GC230

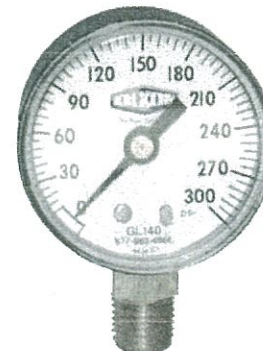
Lower Mount

2" face
 1/4" lower mount

PSI	Fig. Inter.	Minor Grad.	Part #	Price/E
0-15	1	.5	GL100	\$19.20
0-30	5	.5	GL115	17.75
0-60	5	1	GL120	17.75
0-100	10	2	GL125	17.75
0-160	20	5	GL130	17.75
0-200	20	5	GL135	17.75
0-300	30	5	GL140	17.75

2½" face
 1/4" lower mount

PSI	Fig. Inter.	Minor Grad.	Part #	Price/E
0-15	1	.5	GL300	\$20.40
0-30	5	.5	GL320	18.95
0-60	5	1	GL325	18.95
0-100	10	2	GL330	18.95
0-160	20	5	GL335	18.95
0-200	20	5	GL340	18.95
0-300	30	5	GL345	18.95
0-400	50	10	GL347	18.95
0-600	50	10	GL350	18.95
0-1000	200	20	GL355	28.10
0-1500	300	50	GL360	28.10
0-2000	400	50	GL365	28.10
0-3000	500	100	GL370	28.10
0-5000	1000	100	GL375	28.10



GL140

3½" face
 1/4" lower mount

PSI	Fig. Inter.	Minor Grad.	Part #	Price/E
0-15	1	.5	GS15-4	\$28.10
0-30	5	.5	GS30-4	26.60
0-60	5	1	GS60-4	26.60
0-100	10	2	GS100-4	26.60
0-160	20	5	GS160-4	26.60
0-200	20	5	GS200-4	26.60
0-300	30	5	GS300-4	26.60
0-400	50	10	GS400-4	26.60
0-600	50	10	GS600-4	26.60
0-1000	200	20	GS1000-4	36.95

SMITH-COOPER

INTERNATIONAL

BALL VALVES

172 8155 Series
172 8156 Series

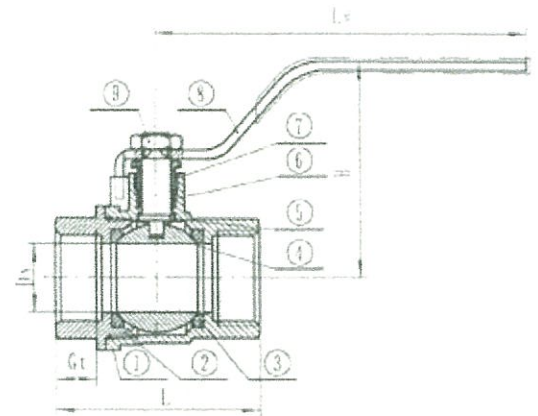
ECONOMY FULL PORT BALL VALVES

- 600# WOG, 150# WSP
- Full Port
- Chrome Plated Brass Ball
- CSA 3-88 for 5 psig (1/2" - 2")
- CSA-Z21.15a for 1/2 psig (1/2" - 2")
- Blow Out Proof Stem
- PTFE Seats and Seals
- ISO 9001 Manufacturer

No. Part

①	Body	Forged Brass ASTM B-124, C37700
②	Body End Cap	Forged Brass ASTM B-124, C37700
③	Ball Seat	PTFE
④	Ball	Chrome Plated Brass ASTM B-124, C37700
⑤	Stem	Brass ASTM B-124, C37700
⑥	Stem Packing	PTFE
⑦	Packing Nut	Brass ASTM B-124, C37700
⑧	Handle	Forged Steel ASTM A-283 (Zinc Plated)
⑨	Nut	Forged Steel ASTM A-283 (Zinc Plated)

Materials Specification

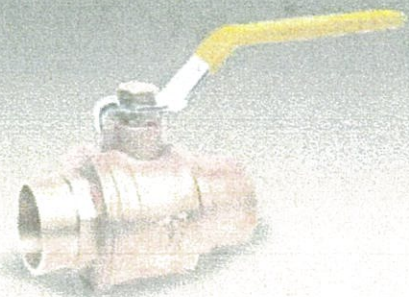
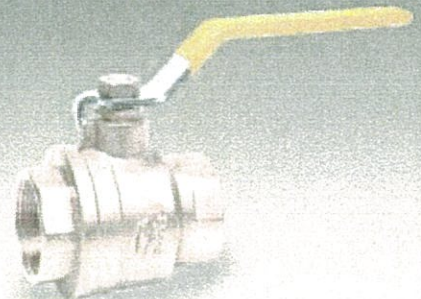


172 8155 SERIES BRASS BALL VALVE, THREADED

Size	Fig. #	Weight	Box/Case	DN	L	H	GT	LH
1/4"	172 8155 C	0.32	10/160	0.39	1.69	1.62	0.39	3.47
3/8"	172 8155 E	0.39	10/160	0.39	1.69	1.62	0.39	3.47
1/2"	172 8155 G	0.44	10/120	0.59	2.07	1.85	0.51	3.47
3/4"	172 8155 I	0.71	10/60	0.79	2.38	2.13	0.55	4.33
1"	172 8155 K	1.05	6/60	0.99	2.90	2.29	0.66	4.33
1-1/4"	172 8155 L	1.65	4/24	1.26	3.27	2.80	0.67	5.71
1-1/2"	172 8155 M	2.35	4/16	1.58	3.62	3.00	0.68	5.71
2"	172 8155 N	3.31	2/16	1.97	4.41	3.27	0.87	5.71
2-1/2"	172 8155 P	7.89	1/6	2.55	6.00	4.50	1.06	9.25
3"	172 8155 Q	11.68	1/3	2.95	6.50	4.92	1.87	9.25
4"	172 8155 T	22.11	1/2	3.94	7.75	5.75	1.90	10.39

172 8156 SERIES BRASS BALL VALVE, SOLDER END

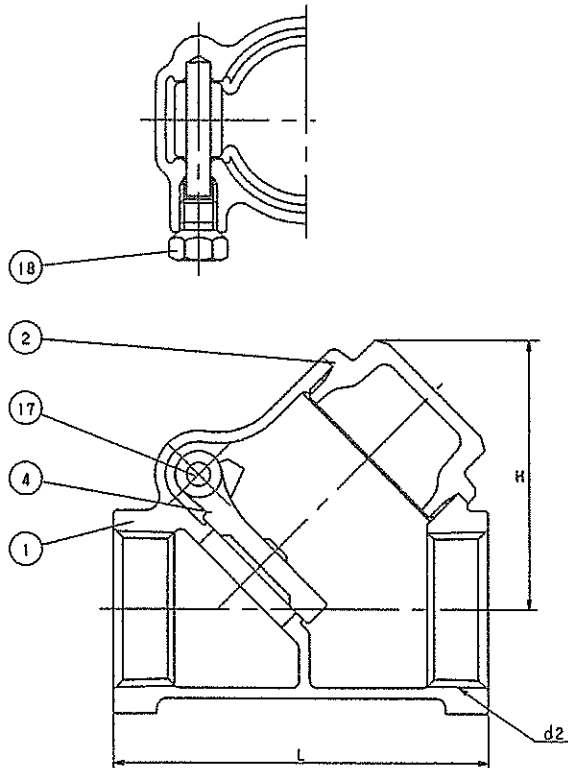
Size	Fig. #	Weight	Box/Case	DN	L	H	GT	LH
1/2"	172 8156 G	0.42	10/120	0.59	2.24	1.85	0.50	3.47
3/4"	172 8156 I	0.66	10/60	0.79	2.82	2.13	0.75	4.33
1"	172 8156 K	0.99	6/60	0.99	3.31	2.29	0.87	4.33
1-1/4"	172 8156 L	1.65	4/24	1.26	4.14	2.80	1.10	5.71
1-1/2"	172 8156 M	2.29	4/16	1.58	4.45	3.00	1.10	5.71
2"	172 8156 N	3.31	2/16	1.97	5.35	3.27	1.34	5.71



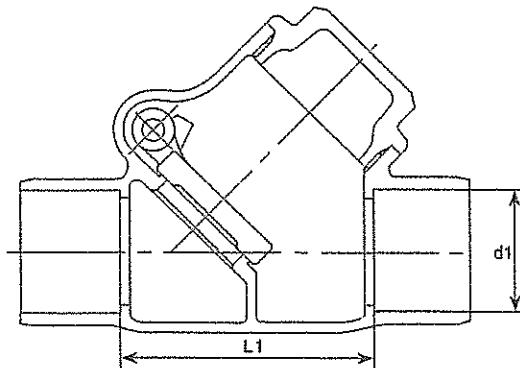
CHECK CLASS 125 BRONZE

Screw Cap • Integral Seat
Y-Pattern Swing Type Disc

CODE # 22 (AKYR) THREADED



CODE # 23 (CYR) SOLDER*



STANDARDS

END TO END	KITZ
THREADED ENDS	ANSI B1.20.1
SOLDER JOINT ENDS	ANSI B16.18
DESIGN	MSS SP-80, TYPE 3
MILITARY	MSS SP-80, TYPE 3

PRESSURE/TEMPERATURE

125 PSI - SATURATED STEAM TO 353°F

- FLUID TO 406°F

200 PSI NON-SHOCK COLD WATER, OIL OR GAS

*SEE PRESSURE TEMPERATURE LIMITATIONS FOR SOLDER JOINT
VALVES - PAGE BIV-50.

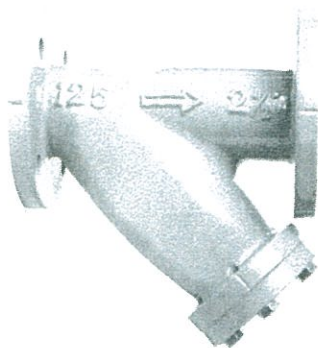
MATERIAL LIST

NO.	NAME OF PART	SPECIFICATION
1	BODY	CAST BRONZE (ASTM B62)
2	CAP	FORGED BRASS (B283, C37700)
4	DISC	CAST BRONZE (ASTM B62)
17	HINGE PIN	COPPER
18	PLUG	BRASS ROD (B16)

DIMENSIONS - WEIGHTS - QUANTITIES

d2 SIZE	H	L	L1	d1 Max.	d1 Min.	APPROX. NET WT.	CARTON QTY
1/2	1.57	2.20	1.64	.631	.627	0.52	96
3/4	1.93	2.76	1.88	.881	.877	0.88	60
1	2.28	3.15	2.31	1.132	1.128	1.33	48
1 1/4	2.80	3.74	2.83	1.382	1.378	2.04	24
1 1/2	3.15	4.33	3.21	1.633	1.628	2.78	18
2	3.74	5.04	4.02	2.133	2.128	4.58	12
2 1/2	4.49	6.14	4.69	2.633	2.628	7.67	6
3	5.16	7.24	5.42	3.133	3.128	11.00	4

SPECIFICATION SUBMITTAL SHEET



APPLICATION

DOMESTIC Y-STRAINER

Designed for installation on potable water lines to protect downstream equipment from malfunction or premature failure due to build-up of sediment or debris. Coated with FDA Epoxy Coating inside and out.

STANDARDS COMPLIANCE

- MIL-S 16293F Type 2
- Lead Plumbing Law* Certified by IAPMO R&T

*(0.25% MAX. WEIGHTED AVERAGE LEAD CONTENT)

FEATURES

Sizes: ☐ 2 1/2" ☒ 3" ☐ 4" ☐ 6" ☐ 8" ☐ 10" ☐ 12"

Pressure/temperature: 200 psi @ 150°F WOG
125 psi @ 450°F Steam

End connections: Flanged Class 125 lb

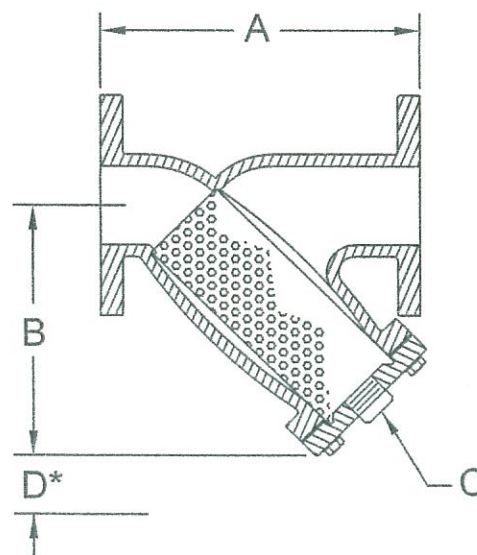
(Closure plug not furnished)

MATERIALS

Main valve body	Cast Iron ASTM A 126 Class B
Access cover	Cast Iron ASTM A 126 Class B
Coatings	FDA Approved Epoxy Coating
Screens	Perforated Stainless Steel, 300 Series

SCREEN

SIZE	SCREEN GAGE	OPENINGS DIA.	OPEN AREA	SCREEN AREA(in ²)
2 1/2	28	1/16	30%	70.01
3	28	1/16	30%	61.34
4	28	1/16	30%	99.64
6	24	1/8	43%	242.72
8	24	1/8	43%	411.16
10	24	1/8	43%	610.51
12	24	1/8	43%	835.53



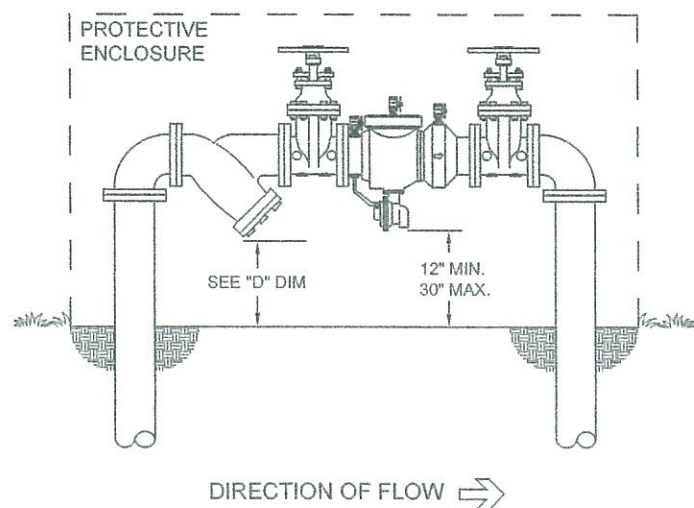
SIZE		DIMENSIONS (approximate)							WEIGHT	
		A		B		C	D*			
in	mm	in	mm	in	mm			in	mm	lbs.
2 1/2	65	9 7/8	251	8 3/8	213	1 1/4 NPT	6	152	35	16
3	80	10 1/4	260	7 3/8	187	1 NPT	6	152	35	16
4	100	12 1/8	308	8 3/4	222	1-1/2 NPT	9	229	65	29
6	150	18 9/16	471	14	356	2 NPT	10	254	155	70
8	200	24 1/8	613	17 3/4	451	2 NPT	11	279	240	109
10	250	29 9/16	751	21 1/4	540	2 NPT	14	356	400	181
12	300	33 3/4	857	24	610	2 NPT	17	432	500	227

*Vertical clearance for screen removal

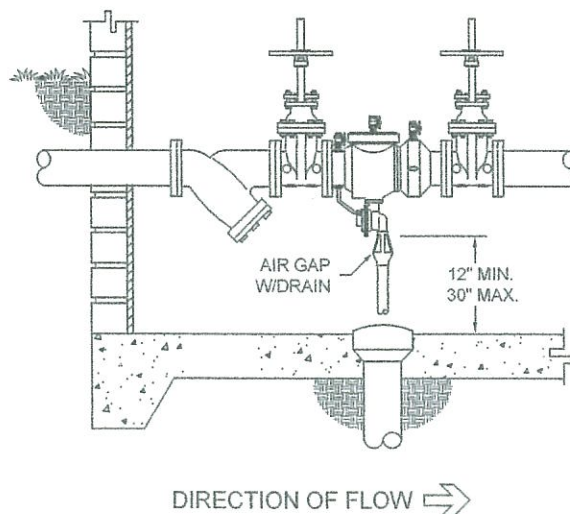
Capacity thru Schedule 40 Pipe (GPM)				
Pipe Size	5 ft/sec	7.5 ft/sec	10 ft/sec	15 ft/sec
2 1/2"	75	112	149	224
3"	115	173	230	346
4"	198	298	397	595
6"	450	675	900	1351
8"	780	1169	1559	2339
10"	1229	1843	2458	3687
12"	1744	2617	3489	5233

TYPICAL INSTALLATION

Local codes shall govern installation requirements. Unless otherwise specified, the assembly shall be mounted with sufficient clearance for maintenance in accordance with the manufacturers' instructions and the latest edition of the Uniform Plumbing Code. The installation shall be made so that no part of the unit can be submerged. Horizontal installation with the strainer cap facing downward is the preferred installation orientation; however the strainer will provide protection in any orientation



OUTDOOR INSTALLATION



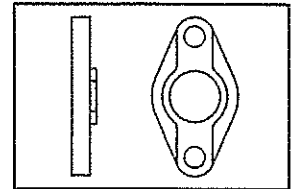
INDOOR INSTALLATION

SPECIFICATIONS

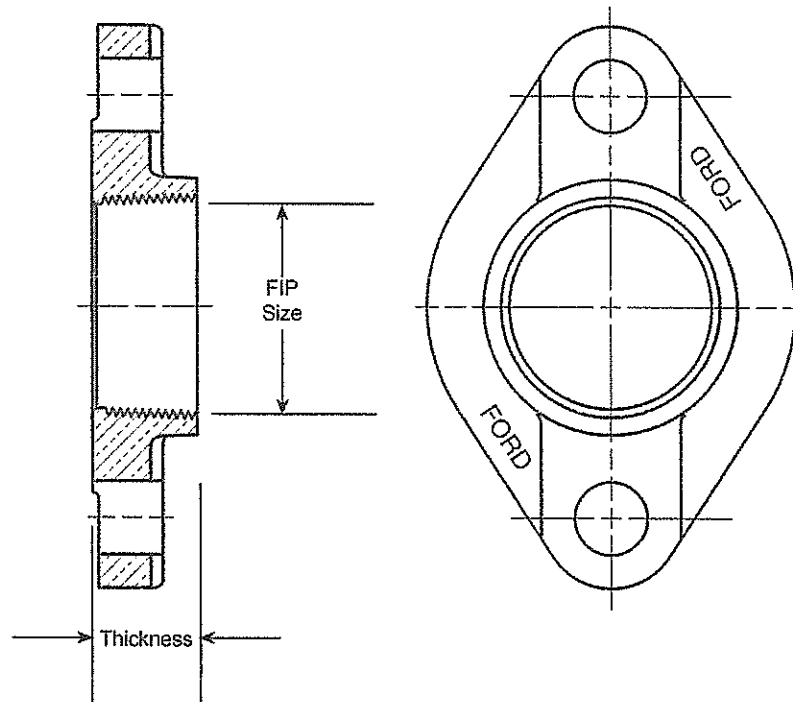
The Cast Iron "Y" type strainer shall be in compliance with MIL-S-16293F Type 2. The main body and access cover shall be cast iron (ASTM A 126 Class B) and coated with a FDA approved epoxy coating inside and out. The integral strainer screen shall be accessible for cleaning without removing the device from the line. The Cast Iron "Y" type strainer shall be a WILKINS Model FSC-DOM.

SUBMITTAL INFORMATION

Meter Flange - (CF31-xx style)



METER FLANGE BY FEMALE IRON PIPE THREAD



DESCRIPTION	THICKNESS	APPROX. WT. LBS	PART NUMBER	✓ SUBMITTED ITEM(S)
1-1/2" Meter Flange x 1-1/2" Female IP	1"	2.4	▼ CF31-66	
1-1/2" Meter Flange x 2" Female IP Thread	1"	1.9	▼ CF31-67	
2" Meter Flange x 2" Female IP Thread	1-1/8"	3.0	▼ CF31-77	
2" Meter Flange x 2-1/2" Female IP Thread	1-1/8"	2.6	CF31-78	

▼ UL Classified to ANSI/NSF Standard 61.



FEATURES

- All brass conforms to AWWA Standard C800 (ASTM B-62 and ASTM B-584, UNS NO C83600 - 85-5-5-5)
- Drop-in meter gaskets are included with all 1-1/2" and 2" meter flanges.

Optional slotted bolt holes on 2" flanges to accomodate 1-1/2" meters.

The Ford Meter Box Company considers the information in this submittal form to be correct at the time of publication. Item and option availability, including specifications, are subject to change without notice. Please verify that your product information is current.



The Ford Meter Box Company, Inc.
P.O. Box 443, Wabash, Indiana U.S.A. 46992-0443
Phone: 260-563-3171 / Fax: 800-826-3487
Overseas Fax: 260-563-0167
<http://www.fordmeterbox.com>

07/01/04

Submitted By:

Model 500XL

Water Pressure Reducing Valve with Integral By-pass Check Valve

Application

Ideal for use where Lead-Free* valves are required. Designed for installation on potable water lines to reduce high inlet pressure to a lower outlet pressure. The high flow capacity makes this device most suitable for industrial water lines and commercial irrigation systems. The direct acting integral by-pass design prevents buildup of excessive system pressure caused by thermal expansion. The balanced piston design enables the regulator to react in a smooth and responsive manner to changes in system flow demand, while at the same time, providing protection from inlet pressure changes.

Standards Compliance

- ASSE® Listed 1003 (1/2" thru 2 1/2")
 - IAPMO® Listed (1/2" thru 2")
 - CSA® Certified (1/2" thru 2")
 - City of Los Angeles Approved (1/2" thru 2")
 - NSF® Listed - Standard 61, Annex G*
 - Certified to NSF/ANSI 372* by IAPMO R&T
- *(0.25% MAX. WEIGHTED AVERAGE LEAD CONTENT)

Materials

Main valve body	Cast bronze	ASTM B 584
Access covers	Cast bronze	ASTM B 584
	Low Lead Brass	
Fasteners	Stainless steel, 300 series	
Stem & plunger	Cast bronze	ASTM B 584
	Low Lead Brass	
Elastomers	Buna Nitrile (FDA approved)	
	EPDM (FDA approved)	
Cap gaskets	Natural vulcanized fibre	
	Acetal (Delrin™ 500), NSF Listed	
Springs	Oil tempered wire, ASTM A 229	
Seat	Stainless steel, 300 series	

Features

Sizes:	1/2", 3/4", 1", 1 1/4", 1 1/2", 2", 2 1/2", 3"
Maximum working water pressure	300 psi
Maximum working water temperature	140° F
Reduced pressure range	25 psi to 75 psi
Factory preset (field set 2 1/2" & 3")	50 psi
Threaded connections (FNPT)	ANSI B1.20.1
Copper connections (FC)	ANSI B 16.22
CPVC tailpiece: Max.hot water temp.	140°F @ 100 psi
	Cold water rated temp. 73.4°F @ 400 psi

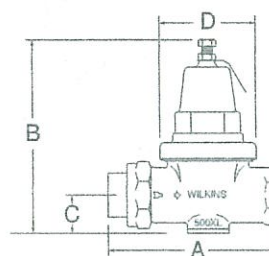


Options (Suffixes can be combined)

- ☐ - standard with single union FNPT inlet x FNPT outlet (1/2" thru 2") and less union (2 1/2" & 3")
- ☐ C - copper sweat connection (1/2" thru 2")
- ☐ HR - 75 psi to 125 psi spring range, factory set at 85 psi (field set 2 1/2" & 3")
- ☐ HLR - 10 psi to 125 psi spring range, factory set at 50 psi
- ☐ HTSTSC - 180°F maximum temp, stainless steel trim, spring, sealed cage
- ☐ L - less integral by-pass check valve (3/4"-2")
- ☐ LPV - 180°F maximum temp with 10 psi to 35 psi spring range, factory set at 20 psi
- ☐ LPC - 140°F maximum temp with 10 psi to 35 psi spring range, factory set at 20 psi
- ☐ SC - sealed cage bell housing and stainless steel adjustment screw
- ☐ YSBR - with lead-free bronze "Y" strainer on inlet
- ☐ 510XL - 400 psi inlet rating and 75 psi to 125 psi spring range, factory set at 85 psi (field set 2 1/2" & 3")
- ☐ P - tapped and plugged for gauge
- ☐ CPVC - CPVC tailpiece connection (3/4"-1")

Accessories

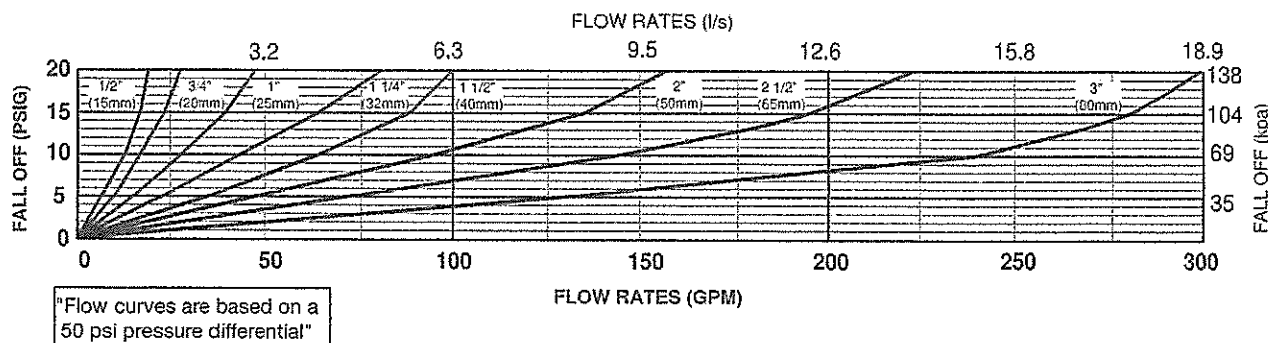
- ☐ Repair kit (rubber only)



Dimensions & Weights (do not include pkg.)

SIZE		CONNECTIONS	DIMENSIONS (approximate)								WEIGHT	
			A		B		C		D			
in.	mm		in.	mm	in.	mm	in.	mm	in.	mm	lbs.	kg.
1/2	15	SINGLE UNION	4 1/2	108	6	152	1 5/8	41	2 3/4	70	3	1.5
3/4	20	SINGLE UNION	4 5/8	118	6	152	1 1/8	29	2 3/4	70	4	2.0
1	25	SINGLE UNION	5 1/8	130	6 7/8	175	1 5/8	41	3 5/16	84	6	3.0
1 1/4	32	SINGLE UNION	6 5/16	160	7 1/4	184	1 3/4	45	4	102	7	3.0
1 1/2	40	SINGLE UNION	8 5/16	211	10	254	1 7/8	48	5	127	14	6.5
2	50	SINGLE UNION	9 1/2	241	10 3/4	273	2 1/8	54	6 1/2	165	20	9.0
2 1/2	65	LESS UNION	10	254	14 1/2	368	3	76	8	203	28	12.5
3	80	LESS UNION	11 1/8	283	16	406	3 1/2	89	8	203	44	20.0

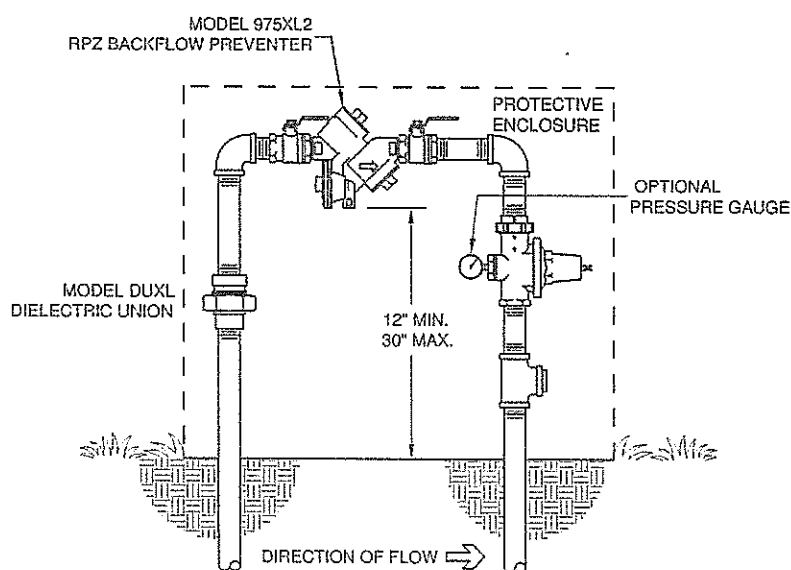
MODEL 500XL 1/2" THRU 3" (STANDARD & METRIC)



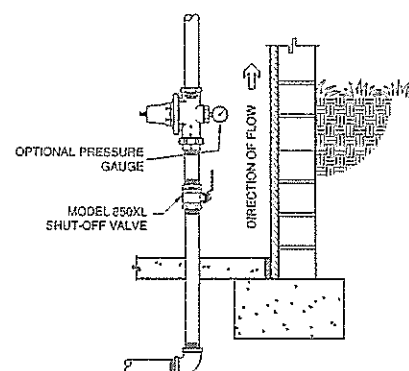
Typical Installation

Local codes shall govern installation requirements. Unless otherwise specified, the assembly shall be mounted in accordance with the manufacturers' instructions and the latest edition of the Uniform Plumbing Code. The assembly shall be installed with sufficient side clearance for testing and maintenance. The Model 500XL may be installed in any position. If installed in a pit, vault, or inside application, specify the "SC" sealed cage option. Multiple installations are recommend for wide demand variations or where the desired pressure reduction is more than 4 to 1 (i.e.: 200 psi inlet reduced to 50 psi outlet).

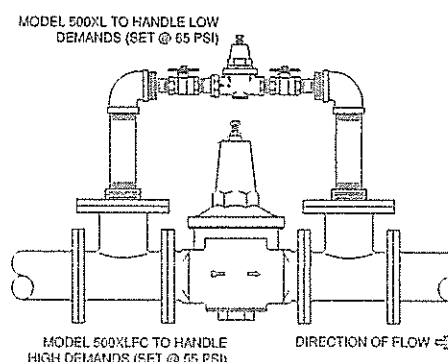
Caution: Anytime a reducing valve is adjusted, a pressure gauge must be used downstream to verify correct pressure setting. Do not bottom adjustment bolt on bell housing.



TYPICAL INSTALLATION



VERTICAL INSTALLATION



BATTERY INSTALLATION

Specifications

The Pressure Reducing Valve shall be certified to NSF/ANSI 372, consisting of a low lead bronze body and bronze bell housing, a separate access cover for the plunger and a bolt to adjust the downstream pressure. The bronze bell housing and access cap shall be threaded to the body and shall not require the use of ferrous screws. The assembly shall be of the balanced piston design and shall reduce pressure in both flow and no-flow conditions. The assembly shall be accessible for maintenance without having to remove the body from the line. The Pressure Reducing Valve shall be a ZURN WILKINS Model 500XL.

PIPE DIMENSIONS AND WEIGHTS

NOMINAL PIPE SIZE INCHES	OUTSIDE DIAMETER INCHES		I.P.S.	SCHEDULE	WALL INCHES	INSIDE DIAMETER INCHES	WT/FT POUNDS
1/8	.405		10S		.049	.307	.1863
		40	40S Std.		.068	.269	.2447
		80	80S Ex. Hvy.		.095	.215	.3145
1/4	.540		10S		.065	.410	.3297
		40	40S Std.		.088	.364	.4248
		80	80S Ex. Hvy.		.199	.302	.5351
3/8	.675		10S		.065	.545	.4235
		40	40S Std.		.091	.493	.5676
		80	80S Ex. Hvy.		.126	.423	.7388
1/2	.840		5S		.065	.710	.5383
			10S		.083	.674	.6710
		40	40S Std.		.109	.622	.8510
		80	80S Ex. Hvy.		.147	.546	1.088
		160	XX Hvy.		.187	.466	1.304
3/4	1.050		5S		.065	.920	.6838
			10S		.083	.884	.8572
		40	40S Std.		.113	.824	1.131
		80	80S Ex. Hvy.		.154	.742	1.474
		160	XX Hvy.		.218	.614	1.937
1	1.315		5S		.065	1.185	.8678
			10S		.109	1.097	1.404
		40	40S Std.		.133	1.049	1.679
		80	80S Ex. Hvy.		.179	.957	2.172
		160	XX Hvy.		.250	.815	2.844
1-1/4	1.660		5S		.065	1.530	1.107
			10S		.109	1.442	1.806
		40	40S Std.		.140	1.380	2.273
		80	80S Ex. Hvy.		.191	1.278	2.997
		160	XX Hvy.		.250	1.160	3.765
1-1/2	1.900		5S		.065	1.770	1.274
			10S		.109	1.682	2.086
		40	40S Std.		.145	1.610	2.718
		80	80S Ex. Hvy.		.200	1.500	3.631
		160	XX Hvy.		.281	1.338	4.859
2	2.375		5S		.065	2.245	1.604
			10S		.109	2.157	2.638
		40	40S Std.		.154	2.067	3.653
		80	80S Ex. Hvy.		.218	1.939	5.022
		160	XX Hvy.		.343	1.689	7.444
2-1/2	2.875		5S		.083	2.709	2.475
			10S		.120	2.635	3.531
		40	40S Std.		.203	2.469	5.793
		80	80S Ex. Hvy.		.276	2.323	7.661
		160	XX Hvy.		.375	2.125	10.01
3	3.500		5S		.083	3.334	3.029
			10S		.120	3.250	4.332
		40	40S Std.		.216	3.068	7.576
		80	80S Ex. Hvy.		.300	2.900	10.25
		160	XX Hvy.		.438	2.624	14.32
3-1/2	4.000	5	5S		.083	3.834	3.472
		10	10S		.120	3.760	4.973
		40	40S Std.		.226	3.548	9.109
		80	80S Ex. Hvy.		.318	3.364	12.50
			XX Hvy.		.636	2.728	22.85

NOMINAL PIPE SIZE INCHES	OUTSIDE DIAMETER INCHES		I.P.S.	SCHEDULE	WALL INCHES	INSIDE DIAMETER INCHES	WT/FT POUNDS
4	4.500		5S		.083	4.334	3.915
			10S		.120	4.260	5.613
		40	40S Std.		.237	4.026	10.79
		80	80S Ex. Hvy.		.337	3.826	14.98
		120			.438	3.624	19.00
4-1/2	5.00		5S		.083	4.834	4.315
			10S		.120	4.760	6.113
		40	40S Std.		.237	4.526	11.79
		80	80S Ex. Hvy.		.337	4.326	15.98
		160	XX Hvy.		.531	4.038	22.51
5	5.563		5S		.109	5.345	6.349
			10S		.134	5.295	7.770
		40	40S Std.		.258	5.047	14.62
		80	80S Ex. Hvy.		.375	4.813	20.78
		120			.500	4.563	27.04
6	6.625		5S		.109	6.407	7.585
			10S		.134	6.357	9.289
		40	40S Std.		.280	6.065	18.97
		80	80S Ex. Hvy.		.432	5.761	28.57
		120			.562	5.491	36.39
7	7.625		5S		.109	7.407	9.914
			10S		.148	7.329	13.40
		20			.250	7.125	22.36
		30			.277	7.071	24.70
		40	40S Std.		.322	7.981	28.55
8	8.625		5S		.109	8.407	9.914
			10S		.148	8.329	13.40
		20			.250	8.125	22.36
		30			.277	8.071	24.70
		40	40S Std.		.322	7.981	28.55
9	9.625		5S		.109	9.407	9.914
			10S		.148	9.329	13.40
		20			.250	9.125	22.36
		30			.277	9.071	24.70
		40	40S Std.		.322	8.981	28.55
10	10.750		5S		.134	10.482	15.19
			10S		.165	10.420	18.70
		20			.250	10.250	28.04
		30			.307	10.136	34.24
		40	40S Std.		.366	10.020	40.48
11	11.750		5S		.134	11.482	15.19
			10S		.165	11.420	18.70
		20			.250	11.250	28.04
		30			.307	11.136	34.24
		40	40S Std.		.366	11.020	40.48
12	12.750		5S		.165	12.420	22.18
			10S		.180	12.390	24.20
		20			.250	12.250	33.38
		30			.330	12.090	43.77
		40	40S Std.		.375	12.000	49.56

NOMINAL PIPE SIZE INCHES	OUTSIDE DIAMETER INCHES	I.P.S.	SCHEDULE	WALL INCHES	INSIDE DIAMETER INCHES	WT/FT POUNDS
12		60		.562	11.626	73.16
		80		.687	11.376	88.51
		100		.843	11.064	107.2
		120		1.000	10.750	125.5
		140		1.125	10.500	139.7
		160		1.312	10.126	160.3
14	14.000	10		.250	13.500	36.71
		20		.312	13.376	45.68
		30	Std.	.375	13.250	54.57
		40		.438	13.124	63.37
			Ex. Hvy.	.500	13.000	72.09
		60		.593	12.814	84.91
		80		.750	12.500	106.1
		100		.937	12.126	130.7
		120		1.093	11.814	150.7
		140		1.250	11.500	160.2
		160		1.406	11.188	189.1
16	16.000	10		.250	15.500	42.05
		20		.312	15.376	52.36
		30	Std.	.375	15.250	62.58
		40		.500	15.000	82.77
		60	Ex. Hvy.	.656	14.688	107.5
		80		.843	14.314	136.5
		100		1.031	13.938	164.8
		120		1.218	13.564	192.3
		140		1.438	13.124	223.5
		160		1.593	12.814	245.1
18	18.000	10		.250	17.500	47.39
		20		.312	17.376	59.03
		30	Std.	.375	17.250	70.59
		40		.438	17.124	82.06
			Ex. Hvy.	.500	17.000	93.45
		60		.562	16.876	104.8
		80		.750	16.500	138.2
		100		.937	16.126	170.8
		120		1.156	15.688	208.0
		140		1.375	15.250	244.1
		160		1.562	14.876	274.2
				1.781	14.438	308.5
20	20.000	10		.250	19.500	52.73
		20		.375	19.250	78.60
		30	Std.	.500	19.000	104.1
		40		.593	18.814	122.9
		60	Ex. Hvy.	.812	18.376	166.4
		80		1.031	17.938	208.9
		100		1.281	17.438	256.1
		120		1.500	17.000	296.4
		140		1.750	16.500	341.1
		160		1.968	16.064	379.0
22	22.000	10		.250	21.500	58.07
		20	Std.	.375	21.250	86.61
		30	X Hvy.	.500	21.000	114.81

NOMINAL PIPE SIZE INCHES	OUTSIDE DIAMETER INCHES	I.P.S.	SCHEDULE	WALL INCHES	INSIDE DIAMETER INCHES	WT/FT POUNDS
22		60		.875	20.250	197.42
		80		1.125	19.750	250.82
		100		1.375	19.250	302.88
		120		1.625	18.750	353.61
		140		1.875	18.250	403.01
		160		2.125	17.750	451.07
24	24.000	10		.250	23.500	63.41
		20		.375	23.250	94.62
			Std.	.500	23.000	125.5
		30		.562	22.876	140.8
		40	Ex. Hvy.	.687	22.626	171.2
		60		.968	22.064	238.1
		80		1.218	21.564	296.4
		100		1.531	20.938	367.4
		120		1.812	20.376	429.4
		140		2.062	19.876	483.1
		160		2.343	19.314	541.9
26	26.000	10		.312	25.376	85.73
		20	Std.	.375	25.250	102.63
			X Hvy.	.500	25.000	136.17
28	28.000	10		.312	27.376	92.41
		20	Std.	.375	27.250	110.64
		30		.500	27.000	146.85
				.625	26.750	182.73
30	30.000	10		.312	29.376	98.93
		20	Std.	.375	29.250	118.65
		30	Ex. Hvy.	.500	29.000	157.53
				.625	28.750	196.08
32	32.000	10		.312	31.376	105.76
			Std.	.375	31.250	126.66
		20		.500	31.000	168.21
		30		.625	30.750	209.43
		40		.688	30.624	229.92
34	34.000	10		.312	33.376	112.43
			Std.	.375	33.250	134.67
		20		.500	33.000	178.69
		30		.625	32.750	222.78
		40		.688	32.624	244.60
36	36.000	10		.312	35.376	118.92
			Std.	.375	35.250	142.7
			Ex. Hvy.	.500	35.000	189.6
42	42.000		Std.	.375	41.250	166.71
		20	X Hvy.	.500	41.000	221.61
		30		.625	40.750	276.17
		40		.750	40.500	330.41
48	48.000		Std.	.375	47.250	190.74
			X Hvy.	.500	47.000	253.65

PIPE:

CARBON Through 60" OD - specs A120, A53, AP15L, A106, A501, and structural grades

STAINLESS Welded through 36"
Seamless through 12"
Grades 304, 304L, 316, 316L, 309, 310, 321, 347

ALLOY SA335 P1, P5, P9, P11, P22
SA333 GR1/6, GR3

YOLOY Complete stock welded and seamless through 20"

TUBING:

Heavy wall seamless mechanical/pressure tubing through 36" OD
Square and rectangular tubing
Military and U.S. Naval specification tubing

FLANGES:

Carbon steel through 72"
Stainless steel through 30"
Special hard to find sizes in stock

FITTINGS:

Carbon steel: Butt weld through 72"
Stainless steel: Butt weld through 48"
3000#/6000# screwed and socket weld
150# screwed
Special schedules and wall sizes

VALVES:

Industrial valves in carbon, alloy, stainless, and Alloy 20
Inventory of all government and shipyard specifications
Approved Level 1 Supplier from stock
Nuclear Approved ASME section 111, 10 CFR 50 Appendix B, and ANSI N45.2
Fully equipped quality assurance department—all NDE testing available.

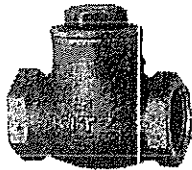
FABRICATION FACILITIES:

12 saws through 36" OD
Beveling, threading, and grooving through 18" OD up to 65 foot long
Special project requirements commercial or code welding

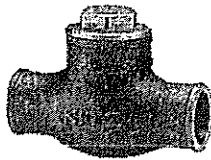
SPECIFICATION	A53 Sizes 1/8"-26" Std., XS and XXS, A.N.S.I. Schedules 10 through 160—Other sizes subject to inquiry.																																						
Scope	Covers seamless and welded BLACK and hot-dipped galvanized nominal (average) wall pipe for coiling, bending, flanging and other special purposes and is suitable for welding. BUTTWELDED pipe is not intended for flanging (roll back operation to form flange using pipe wall). Purpose for which pipe is intended should be stated on order.																																						
Kinds of Steel Permitted For Pipe Material	Open-hearth Electric-furnace	Basic-oxygen																																					
Hot-Dipped Galvanizing	Sets standards for coating of pipe with zinc inside and outside by the hot-dipped process. Weight of coating must not average less than 1.8 oz. per square foot and not less than 1.6 oz. per square foot.																																						
Permissible Variations in Wall Thickness	Same as A120.																																						
Chemical Requirements	<table><tr><td colspan="5">Type S (Seamless pipe) & Type E (electric-weld)</td></tr><tr><td>Open-Hearth, Electric-Furnace or Basic Oxygen</td><td>C</td><td>Mn</td><td>P</td><td>S</td></tr><tr><td>Grade A</td><td>0.25</td><td>0.95</td><td>0.05</td><td>0.06</td></tr><tr><td>Grade B</td><td>0.30</td><td>1.20</td><td>0.05</td><td>0.06</td></tr><tr><td colspan="5">Type F (furnace-welded pipe)</td></tr><tr><td>Open-Hearth, Electric-Furnace or Basic Oxygen</td><td>C</td><td>Mn</td><td>P</td><td>S</td></tr><tr><td></td><td></td><td></td><td>0.08</td><td>0.06</td></tr></table>				Type S (Seamless pipe) & Type E (electric-weld)					Open-Hearth, Electric-Furnace or Basic Oxygen	C	Mn	P	S	Grade A	0.25	0.95	0.05	0.06	Grade B	0.30	1.20	0.05	0.06	Type F (furnace-welded pipe)					Open-Hearth, Electric-Furnace or Basic Oxygen	C	Mn	P	S				0.08	0.06
Type S (Seamless pipe) & Type E (electric-weld)																																							
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			0.08	0.06																																			
Tensile Requirements	<table><tr><td>Buttwelded (furnace-welded)</td><td>Acid-Bessemer</td><td>O.H., Basic Oxygen or Elec. Furn.</td></tr><tr><td>Tensile Strength min., psi</td><td>50,000</td><td>45,000</td></tr><tr><td>Yield Point min., psi</td><td>30,000</td><td>25,000</td></tr><tr><td>Seamless or Electric-Weld</td><td>Grade A</td><td>Grade B</td></tr><tr><td>Tensile Strength min., psi</td><td>48,000</td><td>60,000</td></tr><tr><td>Yield Point min., psi</td><td>30,000</td><td>35,000</td></tr></table>				Buttwelded (furnace-welded)	Acid-Bessemer	O.H., Basic Oxygen or Elec. Furn.	Tensile Strength min., psi	50,000	45,000	Yield Point min., psi	30,000	25,000	Seamless or Electric-Weld	Grade A	Grade B	Tensile Strength min., psi	48,000	60,000	Yield Point min., psi	30,000	35,000																	
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Tensile Strength min., psi	48,000	60,000																																					
Yield Point min., psi	30,000	35,000																																					
Hydrostatic Testing	Hydrostatic inspection test pressures for plain end and threaded and coupled pipe are specified. Hydrostatic pressure shall be maintained for not less than 5 seconds for all sizes of seamless and electric-weld pipe.																																						
Permissible Variations in Weights per Foot	For Extra Strong and lighter wall thicknesses Plus or Minus 5% For heavier than extra strong wall thicknesses Plus or Minus 10%																																						
Permissible Variations in Outside Diameter	Same as A120.																																						
Mechanical Tests Specified	Tensile Test—Transverse required on EW sizes 8 1/2" and larger. Bending Test (Cold) Std. and XS-2" and under. XXS-1 1/4" and under. Degree of Bend For Normal A53 Uses 90 For Close Coiling 180 Diameter of Mandrel 12 x nom. dia. of pipe 8 x nom. dia. of pipe Flattening Test 2 1/2" and larger Std. and XS. (Not required for XXS pipe).																																						
Number of Tests Required	Seamless and Buttweld—Bending, flattening tensile on one length of pipe from each lot of 500 lengths or less of a size. Electric-Weld—Bending and tensile on one length of pipe from each lot of 500 lengths or less of a size. Electric-Weld—Flattening on both crop ends of each length. (Coil, in case of multiple lengths.)																																						
Lengths	Same as A120. (Lengths longer than single random, heavier wall than XS subject to negotiation.)																																						
Required Markings on Each Length (On Tags attached to each Bundle in case of Bundled Pipe)	Rolled, Stamped or Stenciled Name or brand of manufacturer. Kind of pipe, that is, furnace-buttwelded, EW-A, seamless B, etc. XS—for extra strong. XXS—for double extra strong. ASTM A53. Also necessary to indicate when electric-furnace, Length of pipe. or basic-oxygen steel is used.																																						
General Information	Couplings—Applied handling tight. Couplings, 2" and smaller straight tapped, other sizes taper tapped. Line pipe couplings may be specified. Thread Protection—Same as specified under A120. End Finish (unless otherwise specified) Std. or XS, or wall thicknesses less than 0.500 in. (excluding XXS): Plain end beveled. EW pipe may be furnished cold expanded. All XXS and wall thicknesses over 0.500 in.: Plain end square cut.																																						

CLASS 125 BRONZE SWING CHECK VALVEScrewed Cap, Swing type disc
Threaded ends to BS21 (JIS B0203) or NPT,
or solder joint ends.

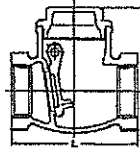
W.O.G. non-shock 1.38 MPa (200 psi), Saturated steam pressure 0.86 MPa (125 psi)

**Fig. R**

• Threaded end to BS21 (JIS B0203)

**Fig. CR**• Solder joint ends
to JIS B2011 /
ASME B16.18 (2 1/2 & 3)**Fig. AKR**

• Threaded end to ASME B1.20.1

**Materials**

Parts	Material
Body	Bronze
Cap	Brass/Bronze*
Hinge pin	Brass
Disc	Brass/Bronze*

*Size 4 only

⚠ Solder joint end valves should not be used in service where the temperature of line fluid is higher than the softening point of solder.

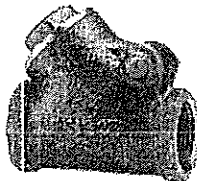
⚠ Don't use for Flammable gas or Toxic gas.

Dimensions

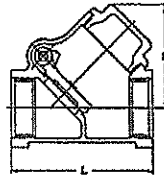
Nominal Size	inch	3/8	1/2	3/4	1	1 1/4	1 1/2	2	2 1/2	3	4	mm
L	mm	10	15	20	25	32	40	50	65	80	100	
L1 Solder		53	60	70	80	92	102	122	150	165	195	
H		39	39	45	52	62	67	79	91	102	119	

CLASS 125 BRONZE Y-PATTERN SWING CHECK VALVEScrewed cap, Swing type disc
Threaded ends to BS21 (JIS B0203)

W.O.G. non-shock 1.38 MPa (200 psi), Saturated steam pressure 0.86 MPa (125 psi)

**Fig. YR**

• Threaded end to BS21 (JIS B0203)

**Materials**

Parts	Material
Body	Bronze
Cap	Brass
Hinge pin	Copper
Disc	Bronze

⚠ Solder joint end valves should not be used in service where the temperature of line fluid is higher than the softening point of solder.

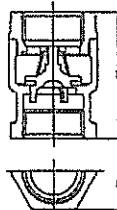
⚠ Don't use for Flammable gas or Toxic gas.

Dimensions

Nominal Size	inch	3/8	1/2	3/4	1	1 1/4	1 1/2	2	mm
L	mm	10	15	20	25	32	40	50	
L		54	56	70	80	95	110	128	
H		40	40	49	58	71	80	95	

CLASS 150 BRONZE LIFT CHECK VALVEScrewed Cap, Lift type disc
Threaded ends to BS21 (JIS B0203) or NPT,
or solder joint ends.

W.O.G. non-shock 1.72 MPa (250 psi)

**Fig. RF**• Threaded end to BS21 (JIS B0203)
• NBR Disc**Fig. CAF**• Solder joint ends
to ASME B16.18
• FKM Disc**Fig. AKAF**• Threaded end to ASME B1.20.1
• FKM Disc**Materials**

Parts	Material
Body	Bronze
Cap	Bronze
Disc	NBR/FKM*

*AKAF & CAF

⚠ Don't use for Flammable gas or Toxic gas.

Dimensions

Nominal Size	inch	1/2	3/4	1	1 1/4	1 1/2	2	mm
L	mm	15	20	25	32	40	50	
L		53	59	67	78	84	98	
L1 Solder		61	76	89	97	110	132	
S (AKAF)		26	32	39	48	54	67	
S (RF)		28	34	41	50	57	70	

KITZ "K-Metal": Unique Dezincification Resistant Brass (UNS No. C35350)

Water pollution and employment of new piping material have amplified valve dezincification problems.

What is dezincification?

The copper alloy used in bronze valves contains zinc, tin, and lead with copper as a base. When bronze valves are subjected to unfavorable service conditions, the zinc component contained in the copper alloy separates from the copper base, and the metal corrodes. This is called dezincification.

In case of bronze valve, the body, bonnet, and other cast bronze parts hardly corrode due to the small percent of zinc contained in the alloy. But brass valve parts such as stems, which contain 40% zinc, often corrodes due to extreme dezincification.

What causes dezincification?

The following factors cause dezincification. These factors are generally believed to occur together, rather than independently.

- 1 Excessive aqueous solution in acidity.
- 2 Warm water containing excessive free carbonic acid with high electric conductivity.
- 3 High electric conductivity with excessive presence of chlorides and sulfides.
- 4 Copper or vinyl chloride pipes.
- 5 Excessive dissolved oxygen.

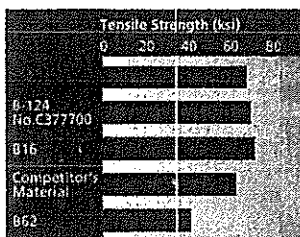


Fig. 1 Compared tensile strength

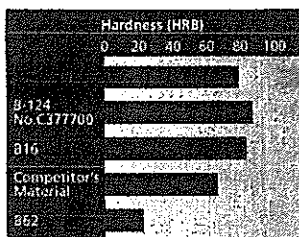


Fig. 2 Compared hardness

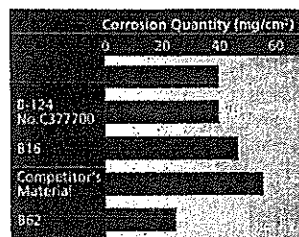


Fig. 3 Compared corrosion
(1mg/cm²=0.014mlb/in²)

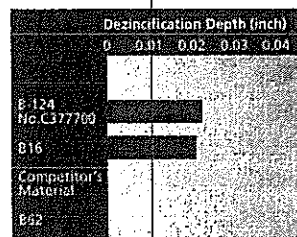


Fig. 4 Compared dezincification
(to AS C316)

Bronze/Brass Valve Solder Joints

Copper tubing is widely used with bronze/brass valves in steam and water-line applications in schools, hospitals, hotels, and private houses because of excellent physical characteristics. It resists corrosion, meets sanitation requirements, and is easy to install.

Copper Tubes: There are three types of copper tubing for complying with ASTM B88 shown below.

Each type is provided with a different wall thickness to meet application requirements.

Type K	For use in steam, oil and gas lines for underground installation and/or severe conditions.
Type L	For general cooling and heating systems and related water piping and ventilation systems.
Type M	For home air-conditioning and heating applications.

CAUTION	Solder joint end valves should not be used in service where the temperature of the line fluid is higher than the softening point of solder.
----------------	---

Soldering Leak-free Joints

Use solder of 95-5 tin-antimony or 96-4 tin-silver, and an open-flame torch. Keep torch temperature relatively low to assure a firmly soldered joint. Because the solder melting point ranges 500°F (260°C) solder jointed valves cannot be used for high temperature service.

Solder P-T Rating

Solder	Max. temp. (°C)	Max. working pressure					
		size 1/4"-1"		size 1/4"-2"		size 2 1/4"-4"	
		MPa	psi	MPa	psi	MPa	psi
95-5 tin-antimony [H95 Sb-5A]	38	3.45	500	2.76	400	2.07	300
	66	2.76	400	2.41	350	1.90	275
96-4 tin-silver [H96 Ag-3.5A]	93	2.07	300	1.72	250	1.38	200
	121	1.38	200	1.21	175	1.03	150

KITZ Bronze and Brass Materials to JIS Standards

JIS H5120-2009 (Copper & Copper Alloy Castings)

Cast bronze Class 6	Designation	Chemical composition (%)										Mechanical property	
		Cu	Sn	Zn	Pb	Ni	Fe	P	Sb	Al	Si	Tensile strength 195 Min. (N/mm ²)	Elongation (%) 15 Min.
	CAC405 (BC6)	83.0-87.0	4.0-6.0	4.0-6.0	4.0-6.0	1.0 Max.	0.3 Max.	0.05 Max.	0.2 Max.	0.01 Max.	0.01 Max.		

JIS H3250-2010 (Copper & Copper Alloy Rods and Bars)

Forged brass Alloy No.3771	Designation		Chemical composition (%)					Mechanical property	
	Extruded	Drawn	Cu	Pb	Fe + Sn	Zn		Tensile strength 315 Min. (N/mm ²)	Elongation (%) 15 Min.
	C3771BE	C3771BD	57.0-61.0	1.0-2.5	1.0 Max.	Remainder			

JIS H3250-2010 (Copper & Copper Alloy Rods and Bars)

Free-cutting brass Alloy No.3604	Designation		Chemical composition (%)					Mechanical property	
	Extruded	Drawn	Cu	Pb	Fe	Fe + Sn	Zn	Tensile strength 335 Min. (N/mm ²)	Elongation (%) —
	C3604BE	C3604BD	57.0-61.0	1.8-3.7	0.5 Max.	1.0 Max.	Remainder		

KITZ Bronze and Brass Materials to ASTM Standards

ASTM B62-2002

		Chemical composition (%)									Mechanical properties		
Copper	Tin	Lead	Zinc	Nickel & cobalt	Iron	Sulfur	Phosphorus	Antimony	Aluminum	Silicon	Minimum		
84.0-86.0	4.0-6.0	4.0-6.0	4.0-6.0	1.0 Max.	0.30 Max.	0.08 Max.	0.05 Max.	0.25 Max.	0.005 Max.	0.005 Max.	Tensile strength 30 ksi	Yield strength 14 ksi	Elongation in 2 in. 20%

ASTM B584 C84400-2004

		Chemical composition (%)									Mechanical properties		
Copper	Tin	Lead	Zinc	Nickel & cobalt	Iron	Sulfur	Phosphorus	Antimony	Aluminum	Silicon	Minimum		
78.0-82.0	2.3-3.5	6.0-8.0	7.0-10.0	1.0 Max.	0.40 Max.	0.08 Max.	0.02 Max.	0.25 Max.	0.005 Max.	0.005 Max.	Tensile strength 29 ksi	Yield strength 13 ksi	Elongation in 2 in. 18%

ASTM B283 C37700-2004

		Chemical composition (%)				Mechanical properties		
Copper		Lead	Iron	Zinc		Minimum		
58.0-61.0		1.5-2.5	0.30 Max.	Remainder		Tensile strength 50 ksi	Yield strength 18 ksi	Elongation in 4x thickness 25%

Compliance with RoHS Requirements.

Aiming to reduce the negative environmental health impact, KITZ CORPORATION can offer products which meet the restriction of the use of six hazardous substances imposed by RoHS* directive of EU, namely mercury, lead, cadmium, hexavalent chromium, PBB and PBDE, to the market. The products meeting this requirement bear the symbol shown below. Please consult KITZ for more details on these products.



*The Restriction of the use of certain Hazardous Substances in electrical and electronic equipment

BOTT WELL PUMP

ECC-8505

One New Caterpillar
Model C32 1200 hp
Industrial Engine

Serial Number:

NST00106

Prepared by:
J. Texeira

Approved by:



Date:

Operation & Maintenance Manual Index

ENGINE INFO

Caterpillar Model C32 Industrial Engine

Engine Serial Number: NST00106

As Shipped Consist

1

Operation & Maintenance Manual C32 Industrial Engines SEBU8599-02 March 2012

C32 Industrial Engine Parts Manual – CD Version SERP5578-00 October 2010

2

CAT Battery Care & Maintenance Guide

Commercial Diesel Engine Fluids Recommendations SEBU6251-14

3

DRAWINGS

Generator Drawing

PLATE HEAT EXCHANGER

Alfa Laval Plate Heat Exchanger Operation & Maintenance Manual

4

EMERGENCY CONTACTS and WARRANTY

Phone Numbers - Oahu

Warranty Statement

Federal Emission Control Warranty

5

AS SHIPPED [NST00106]

SEPTEMBER 26, 2013

For Help Desk Phone Numbers [Click here](#)

The below option will email full breakdown of the serial number	
☒ Excel	☐ PDF
FullBreakDown	

Sales Model: C32 Invoice Number:GE 684717 Dealer: H374 S.O. Number: FPLDY00 Build Date: 2012-05-21

Feature Codes

Reference Number	Eng Chg	Quantity	ASM	LESS	Set Type	Description
C32DI17	F	1	I			C32 ACERT DIT-ATAAC IND ENG 17
EXCCON1	F	1	I			EXHAUST CONNECTION-STRAIGHT N1
FLYHG42	F	1	I			FLYWHEEL HSG-SAE NO. 0 STD DTY
AIRLG06	F	1	I			AIR LINES-90 DEG
ALT2446	F	1	I			CHARGING ALTERNATOR-24V 95AMP
ALTMT03	F	1	I			ALTERNATOR MOUNTING 03
BELT001	F	1	I			POLY VEE BELT 01
CBM0011	F	1	I			CIRCUIT BREAKER MTG-105AMP
CLS0001	F	1	S			COOLING SYSTEM OPTIONS
FLY0000	F	1	I			FLYWHEEL-SAE NO. 0
OLGAG03	F	1	I			OIL LEVEL GAGE-LH
ENG SUP2	F	1	I			FRONT & REAR ENGINE SUPPORTS
PULLEY6	F	1	I			PULLEY-POLY VEE
ELSMDL0	F	1	I			ELECTRIC START MOTOR DUAL 24V
SASETH5	F	1	S			ETHER STARTING AID-24V STD
EUDEDOI	F	1	I			EUROPEAN DIRECTIVE ENGINE DOI
1800RPM	F	1	I			1800 RPM
CGTOTH	F	1	I			THROTTLE POSITION SENSOR-OTHER
EXHREAR	F	1	I			REAR FACING EXHAUST
INDUSTC	F	1	I			INDUST INTERMITTENT C RATING
INDUSTR	F	1	I			INDUSTRIAL ENGINE
MSINDOE	F	1	I			INDUSTRIAL/OEM
LITENGE	F	1	S			EXTRA ENGLISH LITERATURE (1-6)
SPEC PNT	F	1	I			SPECIAL PAINT
MSCIK51	F	1	I			CHIPPPERS/GRINDERS
MWCODD	F	1	I			MECHANICAL DRIVE
HP01125	F	1	I			1125 BHP (839 BKW) W/O FAN
CERTF4A	F	1	I			EPA/CARB TIER 4 INTERIM
0V2329	F	1	I			PSD05
3805822	F	1	I	L		PSD05
3512731	F	1	I			PSD05

Part Numbers

Reference Number	Eng Chg	Quantity	ASM	LESS	Set Type	Description	BreakDown
GP1653	04	1	I			C32C IND DITTA T4I REAR EXH	BreakDown...

- 3435458	00	1	I	ENGINE AR-CORE	BreakDown...
- 5P2506	00	1	S	LITERATURE - ENGLISH	BreakDown...
- 1884641	01	1	I	LINES GP-ENG OIL	BreakDown...
- 2352014	01	1	I	LIFTING GP	BreakDown...
- 2406054	02	1	S	CONNECTION GP	BreakDown...
- 2639766	00	1	I	PLUG GP-HEAD	BreakDown...
- 2696960	00	1	I	COVER GP-OIL	BreakDown...
- 2726645	02	1	I	PLUG GP-BLOCK	BreakDown...
- 2726646	01	1	I	PLUG GP-BLOCK	BreakDown...
- 2726648	00	1	I	PLUG GP-BLOCK	BreakDown...
- 2726649	00	1	I	COVER GP	BreakDown...
- 2784343	01	1	I	LUBRICANT GP-A	BreakDown...
- 2796017	00	1	I	ELBOW GP - WATER	BreakDown...
- 2796020	00	1	I	PLUG GP - HEAD	BreakDown...
- 2796021	00	1	I	PLUG GP-HEAD	BreakDown...
- 2796023	00	1	I	PLUG GP - HEAD	BreakDown...
- 2807368	02	1	I	INSTRUCTIONS - R	BreakDown...
- 3187207	00	1	I	SUPPORT GP - REAR	BreakDown...
- 3317465	01	1	I	PUMP GP-F XFR&C	BreakDown...
- 3430594	04	1	I	MANIFOLD GP - EXHAUST	BreakDown...
- 3447508	04	1	I	LINES GP - OIL	BreakDown...
- 3474107	00	1	I	COVER GP	BreakDown...
- 3474286	02	1	I	CONTROL GP - EGR	BreakDown...
- 3474287	02	1	I	ELBOW GP - AIR	BreakDown...
- 3474291	01	1	I	LINES GP - AIR	BreakDown...
- 3479437	02	1	I	MANIFOLD GP - INTAKE	BreakDown...
- 3482278	01	1	I	LINES GP - WATER	BreakDown...
- 3484037	01	1	I	PUMP GP - WATER	BreakDown...
- 3485203	03	1	I	LINES GP - WATER	BreakDown...
- 3485723	04	1	I	LINES GP-FUEL	BreakDown...
- 3485942	01	1	I	CONT GP - MTG	BreakDown...
- 3491175	00	1	I	FILTER GP - OIL	BreakDown...
- 3492934	02	1	I	TURBO GP - A	BreakDown...
- 3494567	04	1	I	COOLER GP - EXH	BreakDown...
- 3501090	00	1	I	VALVE GP - SOLENOID	BreakDown...
- 3508670	04	1	I	LINES GP - TURBOCHARGER	BreakDown...
- 3509981	00	1	I	INST - PAINT	BreakDown...
- 3509982	03	1	I	COVER GP - SHPG	BreakDown...
- 3510308	02	1	I	SUPPORT GP - FRONT	BreakDown...
- 3518472	02	1	I	COVER GP-MECH -B	BreakDown...
- 3519246	00	1	I	PLUG GP	BreakDown...
- 3519318	01	1	I	PLUG GP	BreakDown...
- 3521578	00	1	I	PLUG GP	BreakDown...
- 3522766	05	1	I	LINES GP-F FIL	BreakDown...
- 3524222	01	1	I	SHIELD GP-TURBO	BreakDown...
- 3529780	02	1	I	WIRING GP - CONT	BreakDown...
- 3550143	01	1	I	FILTER GP-FUEL	BreakDown...

- 3551511	00	1	I	PLUG GP	BreakDown...
- 3558817	01	1	S	WIRING GP - SENSOR	BreakDown...
- 3578002	01	1	I	SENSOR GP - ENGINE	BreakDown...
- 3578963	00	1	S	MANIFOLD GP - MTG	BreakDown...
- 3596798	00	1	I	FILLER GP - OIL	BreakDown...
- 3605920	04	1	I	LINES GP-WATER	BreakDown...
- 3611585	00	1	I	COVER GP	BreakDown...
- 3614465	00	1	I	COVER GP-PAN	BreakDown...
- 3625285	00	1	I	PAN GP-OIL	BreakDown...
- 3655466	01	1	I	LINES GP - AIR	BreakDown...
- 3679441	03	1	I	WIRING GP - CONT	BreakDown...
- 3704577	00	1	I	FITTING GP - FUEL	BreakDown...
- 3722676	04	1	I	LINES GP - WATER	BreakDown...
- 3875552	00	1	I	LINES GP - TURBO - W	BreakDown...
- 3772252	01	1	I	DISPOSAL GP-FUME	BreakDown...
LE7820	01	1	I	0 DEGREE AIR LINES - TURBO EXH	BreakDown...
- 3499673	01	2	I	LINES GP - EXHAUST	BreakDown...
LE7801	01	1	I	FLYWHEEL HOUSING - SAE #0 STD	BreakDown...
- 2241213	06	1	I	GEAR GP. - REAR	BreakDown...
- 2393646	07	1	I	HOUSING GP - FLYWHEEL	BreakDown...
- 2708542	02	1	I	COVER GP	BreakDown...
- 2708580	01	1	I	COVER GP	BreakDown...
- 2708664	01	1	I	COVER GP	BreakDown...
- 2709199	01	1	I	COVER GP	BreakDown...
- 2709200	00	1	I	COVER GP	BreakDown...
- 3611017	00	1	I	COVER GP - SHPG	BreakDown...
- 3104126	00	1	I	COVER GP	BreakDown...
3698013	01	1	I	LINES GP - AIR	BreakDown...
3436828	00	1	I	ALTERNATOR GP	BreakDown...
LE7802	01	1	I	ALTERNATOR MTG	BreakDown...
- 3477094	00	1	I	MTG GP - ALT	BreakDown...
3482223	00	1	I	BELT GP	BreakDown...
3512615	00	1	I	MTG GP - BREAKER	BreakDown...
2399957	02	1	S	SENSOR GP-LEVEL	BreakDown...
2280051	06	1	I	FLYWHEEL GP	BreakDown...
LE7928	00	1	I	LEFT SIDE OIL GAGE	BreakDown...
- 3463292	01	1	I	GAUGE GP - O LEVEL	BreakDown...
PQ0756	01	1	I	FRONT AND REAR ENGINE SUPPORTS	BreakDown...
- 4N4286	08	1	I	REAR ENGINE SUPPORTS	BreakDown...
- 7N9078	01	1	I	SUPPORT GP-ENGINE	BreakDown...
LE7816	00	1	I	MULTI-VEE FEAD PULLEY	BreakDown...
- 3477112	00	1	I	DAMPER GP	BreakDown...
GP1711	00	1	I	C32 T4I DUAL ELECTRIC STARTER	BreakDown...
- 3803654	00	1	I	MOTOR GP-MTG&	BreakDown...

- 3620175	01	1	I	MOTOR GP-ELECSTG	BreakDown...
3524149	00	1	S	AID GP-ETHER STG	BreakDown...
3529860	00	1	I	CERTIFICATION GP (EEC DOI)	BreakDown...
3611818	01	1	I	CERTIFICATION AR	BreakDown...
0V1085		1	I	END USE: INDUSTRIAL/OEM	BreakDown...
0P9715		1	S	EXTRA LITERATURE - ENGLISH	BreakDown...
0P1504		1	I	SPECIAL PAINT-C32 & SMALLER	BreakDown...
GG0485	00	1	I	1125 BHP @ 1800 RPM IND C,	BreakDown...
- 0K4157		1	I	839 BKW (1125 BHP) @ 1800 RPM	BreakDown...
- 0V3925		1	I	EPA NONROAD TIER IV INTERIM EN	BreakDown...
0V2329		1	I	PRODUCTION CORRECTION	BreakDown...
3512731	02	1	I	SHIELD GP - HEAT	BreakDown...

Ship Loose

Reference Number	Eng Chg	Quantity	ASM LESS	Set Type	Description	BreakDown
SEBP5578		2	S		PTSCD	BreakDown...
SEBP5580		2	S		PTSCD	BreakDown...
SEBU8599		2	S		OMM	BreakDown...
SELF5463		2	S		WARRANTY	BreakDown...
2399957		1	S		SENSOR GP-LEVEL	BreakDown...
2406054		1	S		CONNECTION GP -G	BreakDown...
- 5P9074		4	S		WIRE-ELECTRICAL	BreakDown...
- 7C2644		1	S		CLIP	BreakDown...
- 8C3334		2	S		RIVET-TUBULAR	BreakDown...
- 8C6354		1	S		CAP-RECEPTACLE	BreakDown...
- 8T8732		1	S		RECEPTACLE-CONN	BreakDown...
- 8T8736		1	S		RECEPTACLE-CONN	BreakDown...
- 8T8737		68	S		PLUG-SEAL	BreakDown...
- 9W0844		3	S		SOCKET-CONNECTOR	BreakDown...
- 9W0852		2	S		PIN-CONNECTOR	BreakDown...
- 1330967		1	S		PIN-CONNECTOR	BreakDown...
- 1330969		1	S		SOCKET-CONNECTOR	BreakDown...
- 1516320		2	S		TOOL-REMOVAL	BreakDown...
- 1607689		1	S		PLUG AS-CONN	BreakDown...
- 1809339		7	S		PIN-CONNECTOR	BreakDown...
- 1809340		69	S		SOCKET-CONNECTOR	BreakDown...
3524149		1	S		AID GP-ETHER STG	BreakDown...
- 2V1713		1	S		TAG-STARTING AID	BreakDown...
- 3Y2888		2	S		CONNECTOR	BreakDown...
- 5P0640		30	S		WIRE-ELECTRICAL	BreakDown...
- 5P6313		3	S		NUT-FLARELESS	BreakDown...
- 5P6314		3	S		SLEEVE-FLARELESS	BreakDown...
- 7N0140		1	S		TUBE AS-COIL	BreakDown...
- 7N2059		1	S		CLAMP AS-CYL	BreakDown...

- 8C9006	1	S	TEE-UNION	BreakDown...
- 8N3536	1	S	TUBE-STEEL	BreakDown...
- 8T8730	2	S	SOCKET-CONNECTOR	BreakDown...
- 1552261	1	S	WEDGE-PLUG LOCK	BreakDown...
- 1552269	1	S	PLUG AS-CONN	BreakDown...
- 2147568	2	S	SEAL-O-RING-STOR	BreakDown...
- 2391134	1	S	VALVE AS-ETHER	BreakDown...
- 2802562	2	S	ATOMIZER GP	BreakDown...
- 3524151	1	S	INSTRUCTIONS-R	BreakDown...
3558817	1	S	WIRING GP-SENSOR	BreakDown...
- 8L2786	1	S	SEAL-O-RING	BreakDown...
- 2566453	1	S	SENSOR-TEMP	BreakDown...
- 2788844	1	S	PLUG AS.	BreakDown...
3578963	1	S	MANIFOLD GP-MTG&	BreakDown...
- 6V9831	2	S	CAP-ORFS	BreakDown...
- 6V9832	1	S	CAP AS	BreakDown...
- 3498854	1	S	MANIFOLD GP-FUEL	BreakDown...
ESO	1	S	(PRNT ESO COPY)	BreakDown...
6L4502	1	S	PROD MARKING SYS	BreakDown...
- PML	1	S	CHK PM FOR FILMS	BreakDown...

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Operation and Maintenance Manual

C27 and C32 Industrial Engines and C32 Petroleum Engine

SDJ1-Up (C27 Engine)
SDK1-Up (C32 Engine)
RAM1-Up (C27 Engine)
NST1-Up (C32 Engine)

Important Safety Information

Most accidents that involve product operation, maintenance and repair are caused by failure to observe basic safety rules or precautions. An accident can often be avoided by recognizing potentially hazardous situations before an accident occurs. A person must be alert to potential hazards, including human factors that can affect safety. This person should also have the necessary training, skills and tools to perform these functions properly.

Improper operation, lubrication, maintenance or repair of this product can be dangerous and could result in injury or death.

Do not operate or perform any lubrication, maintenance or repair on this product, until you verify that you are authorized to perform this work, and have read and understood the operation, lubrication, maintenance and repair information.

Safety precautions and warnings are provided in this manual and on the product. If these hazard warnings are not heeded, bodily injury or death could occur to you or to other persons.

The hazards are identified by the "Safety Alert Symbol" and followed by a "Signal Word" such as "DANGER", "WARNING" or "CAUTION". The Safety Alert "WARNING" label is shown below.



The meaning of this safety alert symbol is as follows:

Attention! Become Alert! Your Safety is Involved.

The message that appears under the warning explains the hazard and can be either written or pictorially presented.

A non-exhaustive list of operations that may cause product damage are identified by "NOTICE" labels on the product and in this publication.

Caterpillar cannot anticipate every possible circumstance that might involve a potential hazard. The warnings in this publication and on the product are, therefore, not all inclusive. You must not use this product in any manner different from that considered by this manual without first satisfying yourself that you have considered all safety rules and precautions applicable to the operation of the product in the location of use, including site-specific rules and precautions applicable to the worksite. If a tool, procedure, work method or operating technique that is not specifically recommended by Caterpillar is used, you must satisfy yourself that it is safe for you and for others. You should also ensure that you are authorized to perform this work, and that the product will not be damaged or become unsafe by the operation, lubrication, maintenance or repair procedures that you intend to use.

The information, specifications, and illustrations in this publication are on the basis of information that was available at the time that the publication was written. The specifications, torques, pressures, measurements, adjustments, illustrations, and other items can change at any time. These changes can affect the service that is given to the product. Obtain the complete and most current information before you start any job. Cat dealers have the most current information available.



When replacement parts are required for this product Caterpillar recommends using Cat replacement parts or parts with equivalent specifications including, but not limited to, physical dimensions, type, strength and material.

Failure to heed this warning can lead to premature failures, product damage, personal injury or death.

In the United States, the maintenance, replacement, or repair of the emission control devices and systems may be performed by any repair establishment or individual of the owner's choosing.

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Foreword

Literature Information

This manual contains safety, operation instructions, lubrication and maintenance information. This manual should be stored in or near the engine area in a literature holder or literature storage area. Read, study and keep it with the literature and engine information.

English is the primary language for all Cat publications. The English used facilitates translation and consistency in electronic media delivery.

Some photographs or illustrations in this manual show details or attachments that may be different from your engine. Guards and covers may have been removed for illustrative purposes. Continuing improvement and advancement of product design may have caused changes to your engine which are not included in this manual. Whenever a question arises regarding your engine, or this manual, please consult with your Cat dealer for the latest available information.

Safety

This safety section lists basic safety precautions. In addition, this section identifies hazardous, warning situations. Read and understand the basic precautions listed in the safety section before operating or performing lubrication, maintenance and repair on this product.

Operation

Operating techniques outlined in this manual are basic. They assist with developing the skills and techniques required to operate the engine more efficiently and economically. Skill and techniques develop as the operator gains knowledge of the engine and its capabilities.

The operation section is a reference for operators. Photographs and illustrations guide the operator through procedures of inspecting, starting, operating and stopping the engine. This section also includes a discussion of electronic diagnostic information.

Maintenance

The maintenance section is a guide to engine care. The illustrated, step-by-step instructions are grouped by fuel consumption, service hours and/or calendar time maintenance intervals. Items in the maintenance schedule are referenced to detailed instructions that follow.

Use fuel consumption or service hours to determine intervals. Calendar intervals shown (daily, annually, etc.) may be used instead of service meter intervals if they provide more convenient schedules and approximate the indicated service meter reading.

Recommended service should be performed at the appropriate intervals as indicated in the Maintenance Interval Schedule. The actual operating environment of the engine also governs the Maintenance Interval Schedule. Therefore, under extremely severe, dusty, wet or freezing cold operating conditions, more frequent lubrication and maintenance than is specified in the Maintenance Interval Schedule may be necessary.

The maintenance schedule items are organized for a preventive maintenance management program. If the preventive maintenance program is followed, a periodic tune-up is not required. The implementation of a preventive maintenance management program should minimize operating costs through cost avoidances resulting from reductions in unscheduled downtime and failures.

Maintenance Intervals

Perform maintenance on items at multiples of the original requirement. Each level and/or individual items in each level should be shifted ahead or back depending upon your specific maintenance practices, operation and application. We recommend that the maintenance schedules be reproduced and displayed near the engine as a convenient reminder. We also recommend that a maintenance record be maintained as part of the engine's permanent record.

See the section in the Operation and Maintenance Manual, "Maintenance Records" for information regarding documents that are generally accepted as proof of maintenance or repair. Your authorized Cat dealer can assist you in adjusting your maintenance schedule to meet the needs of your operating environment.

Overhaul

Major engine overhaul details are not covered in the Operation and Maintenance Manual except for the interval and the maintenance items in that interval. Major repairs are best left to trained personnel or an authorized Cat dealer. Your Cat dealer offers a variety of options regarding overhaul programs. If you experience a major engine failure, there are also numerous after failure overhaul options available from your Cat dealer. Consult with your dealer for information regarding these options.

California Proposition 65 Warning

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

Battery posts, terminals and related accessories contain lead and lead compounds. **Wash hands after handling.**

Safety Section

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Safety Messages

SMCS Code: 1000; 7405

There may be several specific warning signs on an engine. The exact location of the hazards and the description of the hazards are reviewed in this section. Become familiar with all warning signs.

Ensure that all of the warning signs are legible. Clean the warning signs or replace the warning signs if the words cannot be read or if the pictures are not visible. When the warning signs are cleaned, use a cloth, water, and soap. Do not use solvent, gasoline, or other harsh chemicals to clean the warning signs. Solvents, gasoline, or harsh chemicals could loosen the adhesive that secures the warning signs. The warning signs that are loosened could drop off the engine.

Replace any damaged warning signs or missing warning signs. If a warning sign is attached to a part of the engine that is replaced, install a new warning sign on the replacement part. Any Caterpillar dealer can provide new warning signs.

The warning labels that may be found on the engine are illustrated and described below.

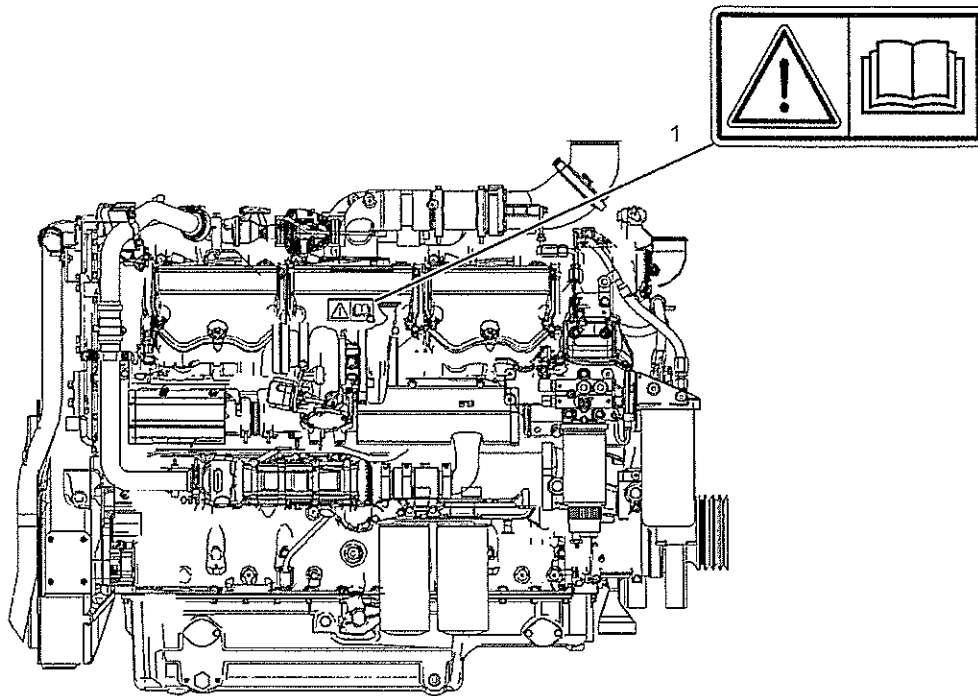


Illustration 1

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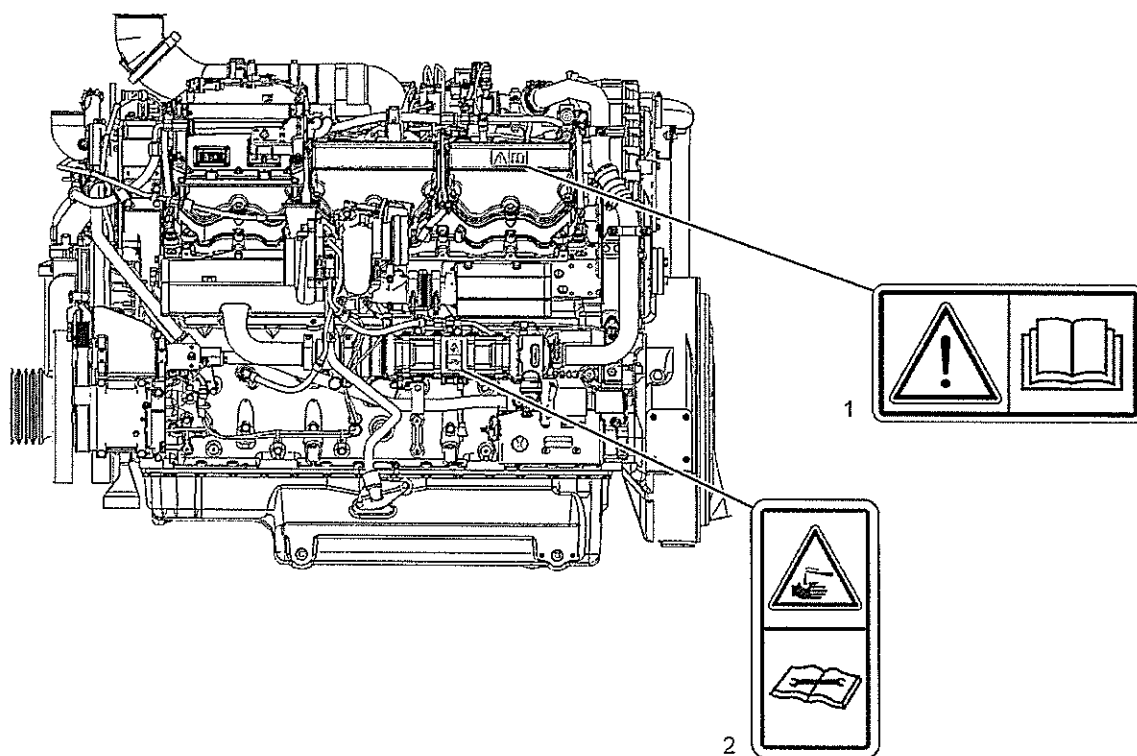
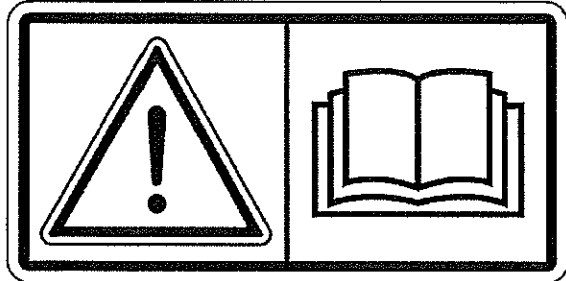


Illustration 2

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Universal Warning (1)

The universal warning label is located on each side of the engine on the valve cover.



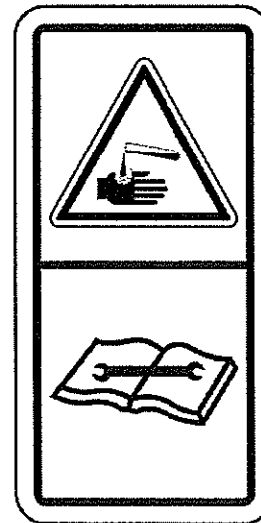
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WARNING

Do not operate or work on this engine unless you have read and understand the instructions and warnings in the Operation and Maintenance Manual. Failure to follow the instructions or heed the warnings could result in injury or death. Contact any Caterpillar dealer for replacement manuals. Proper care is your responsibility.

Acid Burn (2)

This safety message is located on the exhaust cooler.



g01382725

WARNING

Sulfuric Acid Burn Hazard may cause serious personal injury or death.

The exhaust gas cooler may contain a small amount of sulfuric acid. The use of fuel with sulfur levels greater than 15 ppm may increase the amount of sulfuric acid formed. The sulfuric acid may spill from the cooler during service of the engine. The sulfuric acid will burn the eyes, skin and clothing on contact. Always wear the appropriate personal protective equipment (PPE) that is noted on a material safety data sheet (MSDS) for sulfuric acid. Always follow the directions for first aid that are noted on a material safety data sheet (MSDS) for sulfuric acid.

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Burn Prevention

SMCS Code: 1000; 4450; 7405

Do not touch any part of an operating engine. Allow the engine to cool before any maintenance is performed on the engine. Relieve all pressure in the air system, in the hydraulic system, in the lubrication system, in the fuel system, or in the cooling system before any lines, fittings or related items are disconnected.

Coolant

When the engine is at operating temperature, the engine coolant is hot. The coolant is also under pressure. The radiator and all lines to the heaters or to the engine contain hot coolant.

Any contact with hot coolant or with steam can cause severe burns. Allow cooling system components to cool before the cooling system is drained.

Check the coolant level after the engine has stopped and the engine has been allowed to cool.

Ensure that the filler cap is cool before removing the filler cap. The filler cap must be cool enough to touch with a bare hand. Remove the filler cap slowly in order to relieve pressure.

Cooling system conditioner contains alkali. Alkali can cause personal injury. Do not allow alkali to contact the skin, the eyes, or the mouth.

Oils

Hot oil and hot lubricating components can cause personal injury. Do not allow hot oil to contact the skin. Also, do not allow hot components to contact the skin.

Batteries

Electrolyte is an acid. Electrolyte can cause personal injury. Do not allow electrolyte to contact the skin or the eyes. Always wear protective glasses for servicing batteries. Wash hands after touching the batteries and connectors. Use of gloves is recommended.

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Fire Prevention and Explosion Prevention

SMCS Code: 1000; 4450; 7405



Illustration 3

g00704000

Use of personal protection equipment (PPE) may be needed.

All fuels, most lubricants, and some coolant mixtures are flammable.

Always perform a Walk-Around Inspection, which may help you identify a fire hazard. Do not operate a product when a fire hazard exists. Contact your Cat dealer for service.

Flammable fluids that are leaking or spilled onto hot surfaces or onto electrical components can cause a fire. Fire may cause personal injury and property damage.

A flash fire may result if the covers for the engine crankcase are removed within 15 minutes after an emergency shutdown.

Determine whether the engine will be operated in an environment that allows combustible gases to be drawn into the air inlet system. These gases could cause the engine to overspeed. Personal injury, property damage, or engine damage could result.

If the application involves the presence of combustible gases, consult your Cat dealer for additional information about suitable protection devices.

Remove all flammable materials such as fuel, oil, and debris from the engine. Do not allow any flammable materials to accumulate on the engine.

All fluids that are captured in the fluid spill containment basin should be cleaned up immediately. Failure to clean up spilled fluids can cause a fire. Fire may cause personal injury and property damage.

Store fuels and lubricants in properly marked containers away from unauthorized persons. Store oily rags and any flammable materials in protective containers. Do not smoke in areas that are used for storing flammable materials.

Do not expose the engine to any flame.

Exhaust shields (if equipped) protect hot exhaust components from oil or fuel spray in a line, a tube, or a seal failure. Exhaust shields must be installed correctly.

Do not weld on lines or tanks that contain flammable fluids. Do not flame cut lines or tanks that contain flammable fluid. Clean any such lines or tanks thoroughly with a nonflammable solvent prior to welding or flame cutting.

Wiring must be kept in good condition. Properly route and attach all electrical wires. Check all electrical wires daily. Repair any wires that are loose or frayed before you operate the engine. Clean all electrical connections and tighten all electrical connections.

Eliminate all wiring that is unattached or unnecessary. Do not use any wires or cables that are smaller than the recommended gauge. Do not bypass any fuses and/or circuit breakers.

Arcing or sparking could cause a fire. Secure connections, recommended wiring, and properly maintained battery cables will help to prevent arcing or sparking.

Inspect all lines and hoses for wear or for deterioration. Properly route all hoses. The lines and hoses must have adequate support and secure clamps. Tighten all connections to the recommended torque. Leaks can cause fires.

Properly install all oil filters and fuel filters. The filter housings must be tightened to the proper torque.



Illustration 4

g00704059

Use caution when you are refueling an engine. Do not smoke while you are refueling an engine. Do not refuel an engine near open flames or sparks. Always stop the engine before refueling.

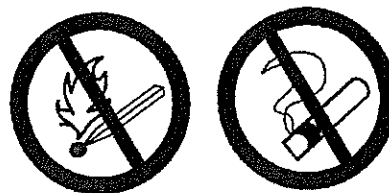


Illustration 5

g02298225

Gases from a battery can explode. Keep any open flames or sparks away from the top of a battery. Do not smoke in battery charging areas.

Never check the battery charge by placing a metal object across the terminal posts. Use a voltmeter or a hydrometer.

Improper jumper cable connections can cause an explosion that can result in injury. Refer to the Operation Section of this manual for specific instructions.

Do not charge a frozen battery. Charging a frozen battery may result in an explosion.

The batteries must be kept clean. The covers (if equipped) must be kept on the cells. Use the recommended cables, connections, and battery box covers when the engine is operated.

Fire Extinguisher

Make sure that a fire extinguisher is available. Be familiar with the operation of the fire extinguisher. Inspect the fire extinguisher and service the fire extinguisher regularly. Obey the recommendations on the instruction plate.

Ether

Ether is flammable and poisonous.

Use ether in well ventilated areas. Do not smoke while you are replacing an ether cylinder or while you are using an ether spray.

Do not store ether cylinders in living areas or in the engine compartment. Do not store ether cylinders in direct sunlight or in temperatures above 49 °C (120 °F). Keep ether cylinders away from open flames or sparks.

Dispose of used ether cylinders properly. Do not puncture an ether cylinder. Keep ether cylinders away from unauthorized personnel.

Do not spray ether into an engine if the engine is equipped with a thermal starting aid for cold weather starting.

Lines, Tubes, and Hoses

Do not bend high-pressure lines. Do not strike high-pressure lines. Do not install any lines that are bent or damaged.

Repair any lines that are loose or damaged. Leaks can cause fires. Consult your Cat dealer for repair or for replacement parts.

Check lines, tubes, and hoses carefully. Do not use your bare hand to check for leaks. Use a board or cardboard to check for leaks. Tighten all connections to the recommended torque.

Replace the parts if any of the following conditions are present:

- End fittings are damaged or leaking.
- Outer coverings are chafed or cut.
- Wires are exposed.
- Outer coverings are ballooning.
- Flexible parts of the hoses are kinked.
- Outer covers have embedded armoring.
- End fittings are displaced.

Make sure that all clamps, guards, and heat shields are installed correctly in order to prevent vibration, rubbing against other parts, and excessive heat.

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Crushing Prevention and Cutting Prevention

SMCS Code: 1000; 4450; 7405

Support the component properly when work beneath the component is performed.

Unless other maintenance instructions are provided, never attempt adjustments while the engine is running.

Stay clear of all rotating parts and of all moving parts. Leave the guards in place until maintenance is performed. After the maintenance is performed, reinstall the guards.

Keep objects away from moving fan blades. The fan blades will throw objects or cut objects.

When objects are struck, wear protective glasses in order to avoid injury to the eyes.

Chips or other debris may fly off objects when objects are struck. Before objects are struck, ensure that no one will be injured by flying debris.

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Mounting and Dismounting

SMCS Code: 1000; 4450; 7405

Inspect the steps, the handholds, and the work area before mounting the engine. Keep these items clean and keep these items in good repair.

Mount the engine and dismount the engine only at locations that have steps and/or handholds. Do not climb on the engine, and do not jump off the engine.

Face the engine in order to mount the engine or dismount the engine. Maintain a three-point contact with the steps and handholds. Use two feet and one hand or use one foot and two hands. Do not use any controls as handholds.

Do not stand on components which cannot support your weight. Use an adequate ladder or use a work platform. Secure the climbing equipment so that the equipment will not move.

Do not carry tools or supplies when you mount the engine or when you dismount the engine. Use a hand line to raise and lower tools or supplies.

i03791210

Sound Information

SMCS Code: 1000

Note: The information that is contained in this Operation and Maintenance Manual, "Sound Information" has not been verified at the time of publication.

Note: Information of the sound level is for machines in European Union countries and in countries that adopt the directives of the European Union.

NOTICE

Hearing protection may be needed when working near an operating generator set.

Sound levels will vary depending on the configuration of the generator set and the final installation of the generator set.

Refer to the following for sound levels:

- The sound pressure level of a complete generator set (including the radiator) at 1 meter is 107 dB(A) for the noisiest configuration when "ISO 8528-10:1998(E) clause 14" is used at 75 percent of the rated power.
- The sound power level of a complete generator set (including the radiator) that is not covered by the "European Union Directive 2000/14/EC" is 118 dB(A) for the noisiest configuration when "ISO 8528-10:1998(E) clause 13" is used at 75 per cent of the rated power.
- The sound pressure level of a partly completed generator set (excluding the radiator) at 1 meter is 104 dB(A) for the noisiest configuration when "ISO 8528-10:1998(E) clause 14" is used at 75 percent of the rated power.
- The sound power level of a partly completed generator set (excluding the radiator) is 114 dB(A) for the noisiest configuration when "ISO 8528-10:1998(E) clause 13" is used at 75 percent of the rated power.

Note: The preceding sound levels are emission levels. The preceding sound levels are not necessarily safe sound levels. There is a correlation between the emission levels and the level of exposure. The correlation between emission levels and the level of exposure cannot be used to determine if further precautions are required.

Refer to the following for factors that influence the level of exposure:

- The characteristics of the area around the generator set
- Other sources of noise
- The number of machines and other adjacent processes
- The length of time of exposure to the noise

This information will enable the user of the machine to evaluate the hazard and the risk.

103560601

Before Starting Engine

SMCS Code: 1000

NOTICE

For initial start-up of a new or rebuilt engine, and for start-up of an engine that has been serviced, make provision to shut the engine off should an overspeed occur. This may be accomplished by shutting off the air and/or fuel supply to the engine.

WARNING

Engine exhaust contains products of combustion which may be harmful to your health. Always start and operate the engine in a well ventilated area and, if in an enclosed area, vent the exhaust to the outside.

Inspect the engine for potential hazards.

Do not start the engine or move any of the controls if there is a "DO NOT OPERATE" warning tag or similar warning tag attached to the start switch or to the controls.

Before starting the engine, ensure that no one is on, underneath, or close to the engine. Ensure that the area is free of personnel.

If equipped, ensure that the lighting system for the engine is suitable for the conditions. Ensure that all lights work properly, if equipped.

All protective guards and all protective covers must be installed if the engine must be started in order to perform service procedures. To help prevent an accident that is caused by parts in rotation, work around the parts carefully.

Do not bypass the automatic shutoff circuits. Do not disable the automatic shutoff circuits. The circuits are provided in order to help prevent personal injury. The circuits are also provided in order to help prevent engine damage.

See the Service Manual for repairs and for adjustments.

i02136012

Engine Starting

SMCS Code: 1000

If a warning tag is attached to the engine start switch or to the controls, DO NOT start the engine or move the controls. Consult with the person that attached the warning tag before the engine is started.

All protective guards and all protective covers must be installed if the engine must be started in order to perform service procedures. To help prevent an accident that is caused by parts in rotation, work around the parts carefully.

If there is a possibility that unburned gas remains in the exhaust system, refer to the purge procedure in this Operation and Maintenance Manual, "Engine Starting" topic in the Operation Section.

Start the engine from the operator's compartment or from the engine start switch.

Always start the engine according to the procedure that is described in the Operation and Maintenance Manual, "Engine Starting" topic in the Operation Section. Knowing the correct procedure will help to prevent major damage to the engine components. Knowing the procedure will also help to prevent personal injury.

To ensure that the jacket water heater (if equipped) and/or the lube oil heater (if equipped) is working properly, check the water temperature and the oil temperature during heater operation.

Engine exhaust contains products of combustion which can be harmful to your health. Always start the engine and operate the engine in a well ventilated area. If the engine is started in an enclosed area, vent the engine exhaust to the outside.

i01462046

Engine Stopping

SMCS Code: 1000

Stop the engine according to the procedure in the Operation and Maintenance Manual, "Engine Stopping (Operation Section)" in order to avoid overheating of the engine and accelerated wear of the engine components.

Use the Emergency Stop Button (if equipped) ONLY in an emergency situation. Do not use the Emergency Stop Button for normal engine stopping. After an emergency stop, DO NOT start the engine until the problem that caused the emergency stop has been corrected.

Stop the engine if an overspeed condition occurs during the initial start-up of a new engine or an engine that has been overhauled. This may be accomplished by shutting off the fuel supply to the engine and/or shutting off the air supply to the engine.

To stop an electronically controlled engine, cut the power to the engine.

i02106213

Electrical System

SMCS Code: 1000; 1400

Never disconnect any charging unit circuit or battery circuit cable from the battery when the charging unit is operating. A spark can cause the combustible gases that are produced by some batteries to ignite.

To help prevent sparks from igniting combustible gases that are produced by some batteries, the negative "-" jump start cable should be connected last from the external power source to the negative "-" terminal of the starting motor. If the starting motor is not equipped with a negative "-" terminal, connect the jump start cable to the engine block.

Check the electrical wires daily for wires that are loose or frayed. Tighten all loose electrical wires before the engine is started. Repair all frayed electrical wires before the engine is started. See the Operation and Maintenance Manual for specific starting instructions.

Grounding Practices

Proper grounding for the engine electrical system is necessary for optimum engine performance and reliability. Improper grounding will result in uncontrolled electrical circuit paths and in unreliable electrical circuit paths.

Uncontrolled electrical circuit paths can result in damage to main bearings, to crankshaft bearing journal surfaces, and to aluminum components.

Engines that are installed without engine-to-frame ground straps can be damaged by electrical discharge.

To ensure that the engine and the engine electrical systems function properly, an engine-to-frame ground strap with a direct path to the battery must be used. This path may be provided by way of a starting motor ground, a starting motor ground to the frame, or a direct engine ground to the frame.

All grounds should be tight and free of corrosion. The engine alternator must be grounded to the negative "-" battery terminal with a wire that is adequate to handle the full charging current of the alternator.

The Engine Monitoring package can vary for different engine models and different engine applications. However, the monitoring system and the engine monitoring control will be similar for all engines.

Note: Many of the engine control systems and display modules that are available for Caterpillar Engines will work in unison with the Engine Monitoring System. Together, the two controls will provide the engine monitoring function for the specific engine application. Refer to the Troubleshooting Manual for more information.

i02784356

Engine Electronics

SMCS Code: 1000; 1900

WARNING

Tampering with the electronic system installation or the OEM wiring installation can be dangerous and could result in personal injury or death and/or engine damage.

This engine has a comprehensive, programmable Engine Monitoring System. The Engine Control Module (ECM) has the ability to monitor the engine operating conditions. If any of the engine parameters extend outside an allowable range, the ECM will initiate an immediate action.

The following actions are available for engine monitoring control: WARNING, DERATE, and SHUTDOWN. These engine monitoring modes have the ability to limit engine speed and/or the engine power.

Many of the parameters that are monitored by the ECM can be programmed for the engine monitoring functions. The following parameters can be monitored as a part of the Engine Monitoring System:

- Operating Altitude
- Engine Coolant Level
- Engine Coolant Temperature
- Engine Oil Pressure
- Engine Speed
- Fuel Temperature
- Intake Manifold Air Temperature
- System Voltage

Product Information Section

General Information

i04002991

Model View Illustrations

SMCS Code: 1000

The following model views show typical features of the engine that is supported in this service module. Due to individual applications, your engine may appear different from the illustrations.

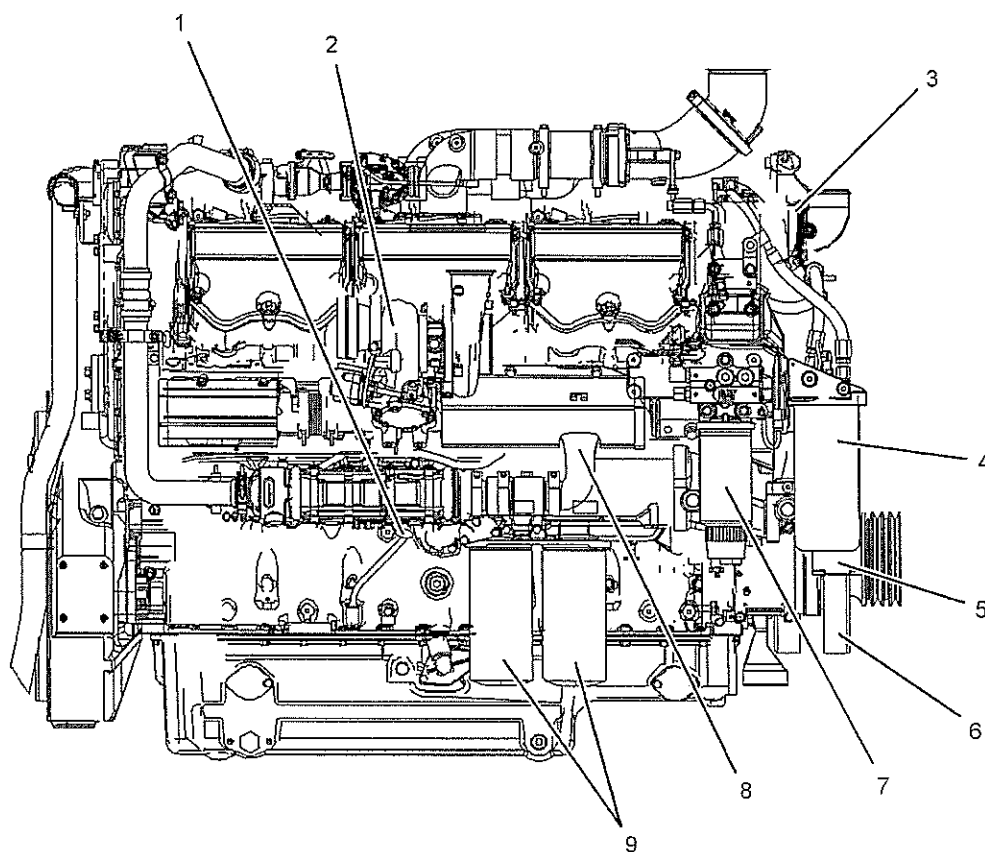


Illustration 6

g02177857

Typical example

- (1) Engine oil level gauge
- (2) Turbocharger
- (3) Water temperature regulator housing

- (4) Secondary fuel filter
- (5) Water pump
- (6) Visconic damper

- (7) Primary fuel filter
- (8) Exhaust manifold
- (9) Engine oil filter

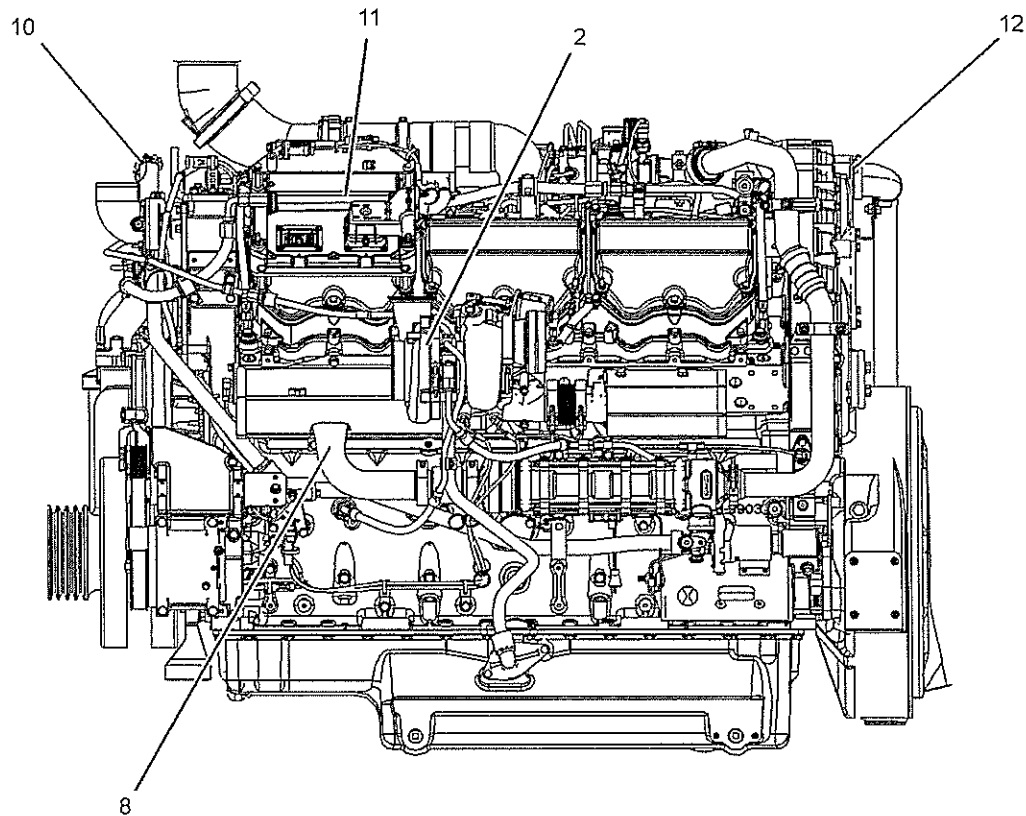


Illustration 7

g02360457

Typical example

(10) Engine oil filler cap

(11) Electronic control module (ECM)

(12) Crankcase breather

i04176237

Product Description

SMCS Code: 1000; 4450; 4491

Caterpillar C27 and C32 Industrial and Petroleum Engines provide the following features:

Engine Description

- Four cycle
- Direct fuel injection
- Mechanical Electronic Unit Injector (MEUI)
- Turbocharged
- Air-To-Air Aftercooler (ATAAC)

Electronic Engine Features

Caterpillar C27 and C32 engines are designed with electronic controls. The integral on board computer controls the operation of the engine. Current operating conditions are monitored. The Electronic Control Module (ECM) controls the response of the engine to these conditions and to the demands of the operator. These conditions and operator demands determine the precise control of fuel injection by the ECM. The electronic engine control system provides the following features:

- Engine and auxiliary monitoring
- Engine speed governing
- Cold start strategy
- Automatic air/fuel ratio control
- Integrated ether start

- Torque rise shaping
- Automatic altitude compensation
- Injection timing control
- System diagnostics

For more information on electronic engine features, refer to the Operation and Maintenance Manual, "Features and Controls" topic (Operation Section).

Engine Cooling and Lubrication

The cooling system consists of the following components:

- Gear-driven centrifugal water pump
- Water temperature regulators which regulate the engine coolant temperature
- Gear-driven oil pump (gear type)
- Oil cooler

The engine lubricating oil is also filtered. Bypass valves provide unrestricted flow of lubrication oil to the engine components during the following conditions:

- High oil viscosity
- Plugged oil cooler or plugged oil filter elements (paper cartridge)

Engine Service Life

Engine efficiency and maximum utilization of engine performance depend on the adherence to proper operation and maintenance recommendations. In addition, use recommended fuels, coolants and lubricants. Use this Operation and Maintenance Manual as a guide for required engine maintenance.

Expected engine life is predicted by the average power that is demanded. The average power that is demanded is based on fuel consumption of the engine over a period of time. For more information, refer to the Operation and Maintenance Manual, "Overhaul Considerations" topic (Maintenance Section).

Engine Specifications

Note: The front end of the engine is opposite the flywheel end of the engine. The left and the right sides of the engine are determined from the flywheel end. The number 1 cylinder is the most forward cylinder.

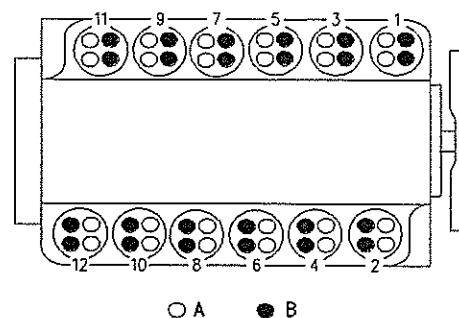


Illustration 8

g00291566

Cylinder and valve locations

(A) Inlet valves
(B) Exhaust valves

Table 1

C27 and C32 Industrial and Petroleum Engine Specifications		
	C27	C32
Cylinders and Arrangement	12 cylinder vee block	
Bore	137.7 mm (5.4 inch)	145 mm (5.7 inch)
Stroke	152.4 mm (6 inch)	162 mm (6.4 inch)
Compression Ratio	16.5:1	15:1
Aspiration	TA ⁽¹⁾	
Displacement	27 L (1648 in ³)	32 L (1953 in ³)
Firing Order	1-10-9-6-5-12-11-4-3-8-7-2	
Rotation (flywheel end)	Counterclockwise	

⁽¹⁾ Turbocharged Aftercooled

Product Identification Information

i04175509

Plate Locations and Film Locations

SMCS Code: 1000; 4450

Caterpillar engines are identified by serial numbers and by arrangement numbers. These numbers are shown on the engine serial number plate and on the engine information plate. Caterpillar dealers need these numbers in order to determine the components that were included with the engine. This permits accurate identification of replacement part numbers.

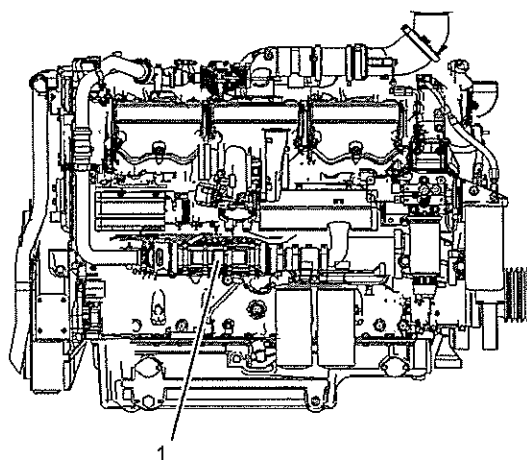


Illustration 9

g02366057

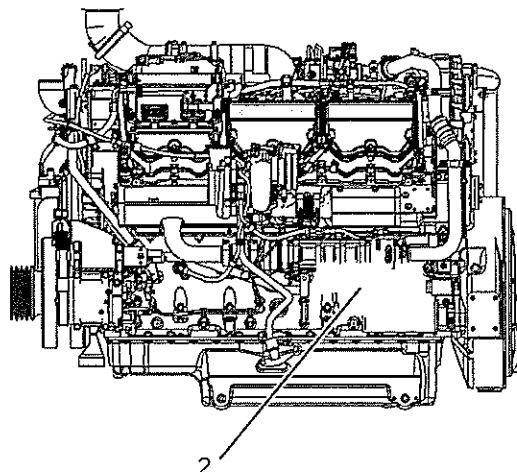


Illustration 10

g02366037

Information Plate (1)

The engine information plate is located on the right side of the engine on the exhaust cooler.

Setpoint of the engine altitude derate _____

Horsepower _____

High idle _____

Full load engine speed _____

Fuel settings _____

The engine information plate also contains other important information about the engine.

Serial Number Plate (2)

The engine serial number plate is located on the left side of the engine block.

Engine serial number _____

Engine model _____

Arrangement number _____

i04019095

Emissions Certification Film

SMCS Code: 1000; 7405

Note: This information is pertinent in the United States, in Canada and in Europe.

Consult your Cat dealer for an Emission Control Warranty Statement.

This label is located on the engine.

i01757910

Reference Information

SMCS Code: 1000; 4450

Identification of the following items may be needed in order to obtain parts and service. Some of the numbers are on the engine Serial Number Plate and/or Information Plate. Locate the information for your engine. Record the information in the appropriate space. Make a copy of this list for a record. Retain the information for future reference.

The top level part numbers in the Parts Manual for the engine are listed with the engine arrangement number.

The packaging arrangement may also be called a pricing arrangement or a customer arrangement. This is the total package with attachments and options that are not included in the engine arrangement.

The performance specification can be used by your Caterpillar dealer with the Technical Marketing Information system. Before the engine leaves the factory, the engine performance is tested. Detailed performance data is recorded. The performance specification number can be used for obtaining the data.

Record for Reference

Engine Model _____

Engine Serial Number _____

Engine Arrangement Number _____

Modification Number _____

Engine Low Idle rpm _____

Engine Full Load rpm _____

Performance Specification Number _____

Part Number for the Primary Fuel Filter _____

Part Number for the Water Separator Element _____

Part Number for the Secondary Fuel Filter Element _____

Part Number for the Lubrication Oil Filter Element _____

Part Number for the Auxiliary Oil Filter Element _____

Part Number for the Supplemental Coolant Additive Maintenance Element (If Equipped) _____

Total Lubrication System Capacity _____

Total Cooling System Capacity _____

Part Number for the Air Cleaner Element _____

Part Number for the Fan Drive Belt _____

Part Number for the Alternator Belt _____

Model Number of the Generator _____

Serial Number of the Generator _____

Arrangement Number of the Generator _____

Part Number for the Control Panel _____

Operation Section

Lifting and Storage

Product Lifting

SMCS Code: 7000; 7002

i02055889

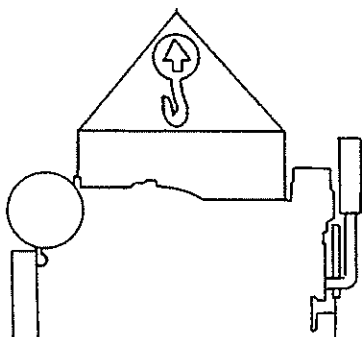


Illustration 11

g00103219

NOTICE

Never bend the eyebolts and the brackets. Only load the eyebolts and the brackets under tension. Remember that the capacity of an eyebolt is less as the angle between the supporting members and the object becomes less than 90 degrees.

When it is necessary to remove a component at an angle, only use a link bracket that is properly rated for the weight.

Use a hoist to remove heavy components. Use an adjustable lifting beam to lift the engine. All supporting members (chains and cables) should be parallel to each other. The chains and cables should be perpendicular to the top of the object that is being lifted.

Some removals require lifting the fixtures in order to obtain proper balance and safety.

To remove the engine ONLY, use the lifting eyes that are on the engine.

Lifting eyes are designed and installed for the specific engine arrangement. Alterations to the lifting eyes and/or the engine make the lifting eyes and the lifting fixtures obsolete. If alterations are made, ensure that proper lifting devices are provided. Consult your Caterpillar dealer for information regarding fixtures for proper engine lifting.

Engine Lifting with a Fuel Tank

⚠ WARNING

Lift eyes or tank can fail when lifting tank containing fluids resulting in possible personal injury. Drain tank of all fluids before lifting.

Lifting the engine with a fuel tank that is mounted to the engine requires special equipment and procedures. Do not lift the unit with fuel in the fuel tank. Consult your Caterpillar dealer for information regarding fixtures for proper lifting of your complete package.

i02375094

Product Storage

SMCS Code: 7002

If the engine will not be started for several weeks, the lubricating oil will drain from the cylinder walls and from the piston rings. Rust can form on the cylinder liner surface. Rust on the cylinder liner surface will cause increased engine wear and a reduction in engine service life.

To help prevent excessive engine wear, use the following guidelines:

- Complete all of the lubrication recommendations that are listed in this Operation and Maintenance Manual, "Maintenance Interval Schedule" (Maintenance Section).
- If freezing temperatures are expected, check the cooling system for adequate protection against freezing. Refer to Special Publication, SEBU6251, "Caterpillar Commercial Diesel Engine Fluids Recommendations", "General Coolant Information".

If an engine is out of operation and if use of the engine is not planned, special precautions should be made. If the engine will be stored for more than one month, a complete protection procedure is recommended.

For more detailed information on engine storage, see Special Instruction, SEHS9031, "Storage Procedure For Caterpillar Products".

Your Caterpillar dealer can assist in preparing the engine for extended storage periods.

Features and Controls

Engine Speed Control (Remote)

i04805677

SMCS Code: 1915

S/N: SDK1-Up

Remote Speed Control - Hand Knob (if equipped)

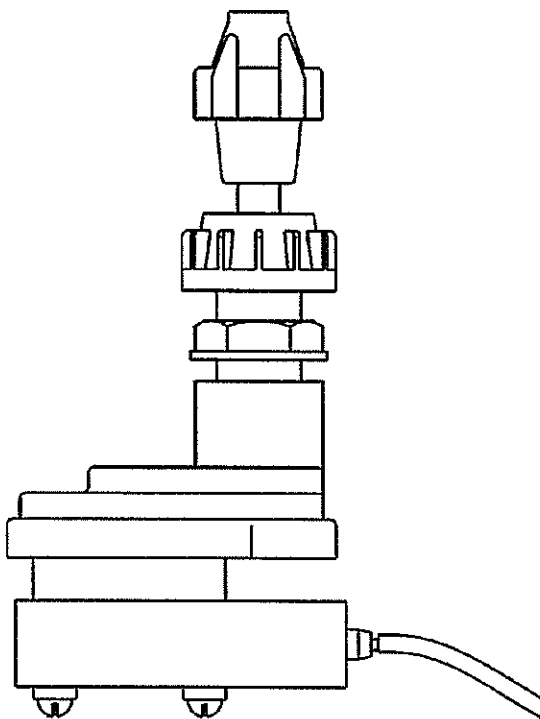


Illustration 12

g02927358

This knob provides full engine rpm control. The knob includes the following: electronic rotary throttle control, 12 V and 24 V operation, twist knob, and locking design. A counter-clockwise turn increases engine speed, with two complete turns of the knob from low to high speed.

Remote Speed Control - Hand Lever (if equipped)

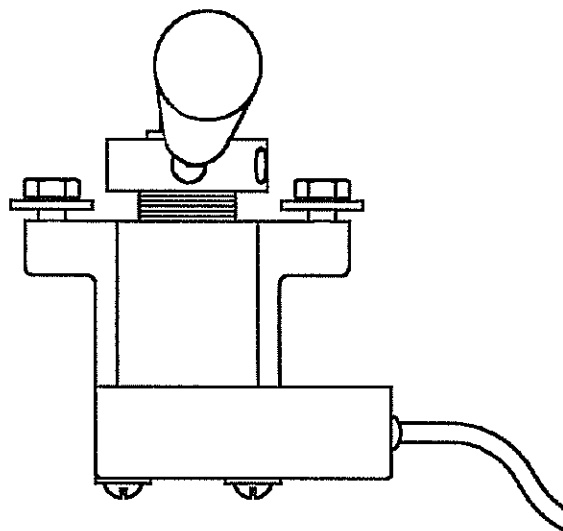


Illustration 13

g02927357

Provides full engine rpm control. The lever includes the following: electronic rotary throttle control and 12 V and 24 V operation. A clockwise turn increases engine speed.

i03953970

Monitoring System (If Equipped)

SMCS Code: 1900; 7400; 7450; 7451

The Monitoring System is designed to alert the operator to an immediate problem with any of the engine systems that are monitored. The Monitoring System is also designed to alert the operator to an impending problem with any of the engine systems that are monitored.

Indicators and Gauges

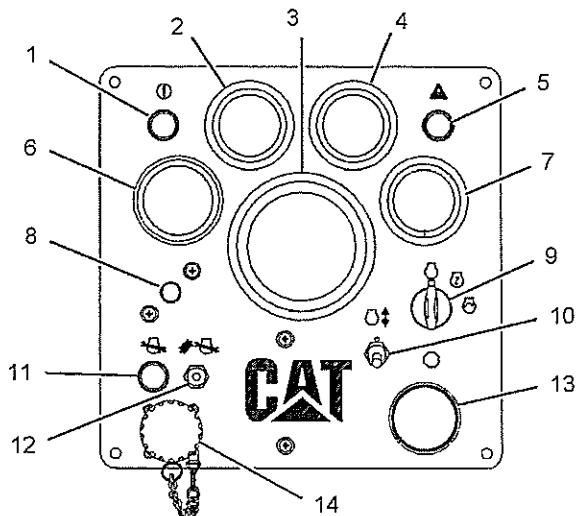


Illustration 14

g01063079

Gauge cluster and indicators



Diagnostic Lamp (1) – The diagnostic lamp is used to indicate the existence of a fault by flashing a fault code. For a more detailed discussion of the diagnostic lamp, please see this Operation and Maintenance Manual, "Diagnostic Lamp" topic.



Engine Oil Pressure (2) – The oil pressure should be greatest after a cold engine is started. The pressure will decrease as the engine warms up. The pressure will increase when the engine rpm is increased. The pressure will stabilize when the engine rpm is stable.

A lower oil pressure is normal at low idle. If the load is stable and the gauge reading changes, perform the following procedure:

1. Remove the load.
2. Reduce engine speed to low idle.
3. Check and maintain the oil level.



Tachometer (3) – This gauge indicates engine speed (rpm). When the throttle control lever is moved to the full throttle position without load, the engine is running at high idle. The engine is running at the full load rpm when the throttle control lever is at the full throttle position with maximum rated load.

NOTICE

To help prevent engine damage, never exceed the high idle rpm. Overspeeding can result in serious damage to the engine. The engine can be operated at high idle without damage, but should never be allowed to exceed high idle rpm.

Note: The high idle rpm and the full load rpm are stamped on the Information Plate.



Coolant Temperature (4) – When the coolant temperature is above the normal operating value, the coolant temperature gauge will be in the red zone. Refer to the Messenger display for any additional information that may be available.



Warning Lamp (5) – There is a general fault in the engine. Refer to the Messenger display for any additional information that may be available.



Fuel Pressure (6) – This gauge indicates fuel pressure to the fuel injection pump from the fuel filter. A decrease in fuel pressure usually indicates a dirty fuel filter or a plugged fuel filter. As the fuel filter becomes plugged, there will be a noticeable reduction in engine performance.



System Voltage (7) – This gauge indicates the voltage of the electrical system.

Circuit Breaker (8) – Reset the circuit breaker if a circuit breaker trips. Press the button in order to reset the circuit breaker. If the electrical system is working properly, the button will remain pressed. If the button does not remain pressed or if the circuit breaker trips soon after being reset, check the appropriate electrical circuit. Repair the electrical circuit, if necessary.

Start Switch (9) – The start switch has three positions: OFF, RUN, and START. When the start switch is turned clockwise to the RUN position, the lamps will flash for 5 seconds during the system test. The lamps will then shut off. In the RUN position, the ECM and electronic systems are powered up.



Idle Speed Switch (10) – When the switch is in the up position, the engine speed increases to HIGH IDLE. When the switch is in the down position, the engine speed decreases to LOW IDLE.



Maintenance Lamp (11) – The ECM records data that is related to equipment maintenance. The ECM will activate the maintenance indicator lamp when scheduled maintenance is due. The maintenance indicator lamp can be reset by actuating the maintenance clear switch. The maintenance interval may be based on operating hours or fuel consumption. The ECM provides information that pertains to maintenance intervals and the last maintenance that was performed.



Maintenance Clear Switch (12) – The maintenance clear switch is required to reset the maintenance lamp after maintenance on the engine is performed.



Shutdown Switch (13) – Use the engine shutdown switch in order to stop the engine. Push the shutdown switch in order to put the switch in the OFF position. After the engine stops, turn the knob clockwise. Turning the knob clockwise will reset the engine shutdown switch to the ON position.

Service Tool Connector (14) – For more information regarding the use of Cat Electronic Technician (ET) and the PC requirements for Cat ET, refer to the documentation.

Caterpillar Messenger Display

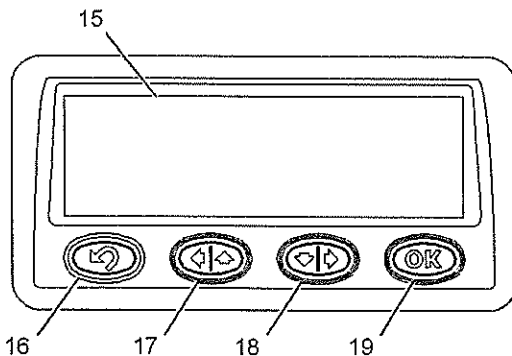


Illustration 15

g01063102

Digital display area (15) – The Messenger system shows information on the digital display area.

Previous button (16) – Use the previous button to return to information that was previously shown on the digital display area.

Scroll up/left button (17) – This button is used to scroll up through information that is shown on the display area. The button can also be used to scroll to the left through information that is shown on the display area.

Scroll down/right button (18) – This button is used to scroll down through information that is shown on the display area. The button can also be used to scroll to the right through information that is shown on the display area.

OK button (19) – Use this button to confirm selections that you have made with the scroll up/left button and the scroll down/right button.

Totals Display

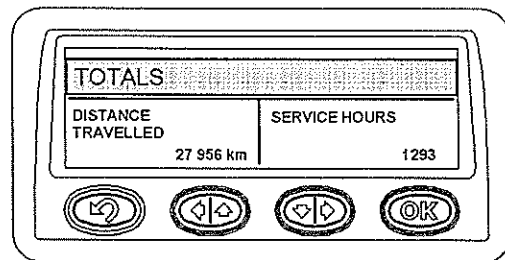


Illustration 16

g01054562

Typical totals display

The following information is available through the display:

CUMULATIVE TOTALS

Service Hours – When you scroll to this option, the display shows the total amount of service hours that the engine has accumulated.

Total Time – When you scroll to this option, the display shows the total hours for the engine ECM.

Total Fuel – When you scroll to this option, the display shows the total amount of fuel that has been consumed.

Settings Display

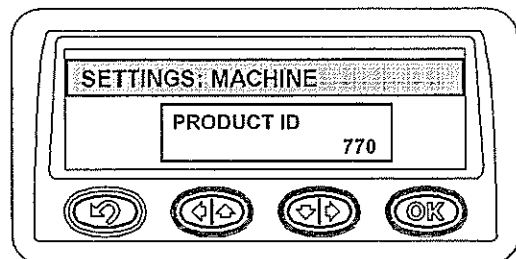


Illustration 17

g01054565

Typical settings display

The following options are available through the payload display:

MONITORING SYSTEM

Language – Select this option to change the language shown on the display.

Units – Select this option to choose the desired measurement system. The choices are metric or English.

Adjust Contrast – Select this option to adjust the contrast of the display in order to improve the visibility of the information.

Adjust Backlight – Select this option to adjust the backlighting of the display in order to improve the visibility of the information.

ENGINE

Equipment ID – Select this option to view the equipment identification number.

Product ID – Select this option to view the product identification number.

Service Display

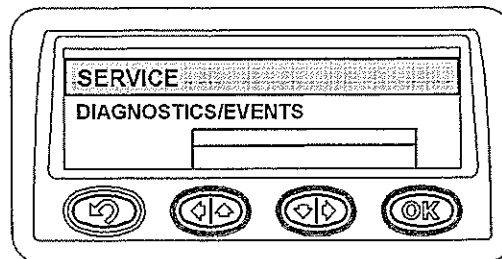


Illustration 18

g01054566

Typical service display

DIAGNOSTICS/EVENTS

The following options are password protected. Enter a password to change the settings.

View – Select this option to view events logged by the monitoring system. If you use an authorized password, you can clear individual events.

Clear All Diagnostics – If you use an authorized password, you can select this option to clear all logged events.

SYSTEM PARAMETERS

MONITORING SYSTEM

- **Battery Voltage:** When you scroll to this option, the battery voltage is displayed.
- **Fuel Level:** When you scroll to this option, the fuel level is displayed.
- **Alternator Status:** When you scroll to this option, the alternator status is displayed.
- **Engine Speed:** When you scroll to this option, the engine RPM is displayed.
- **Desired Engine Speed:** When you scroll to this option, the desired engine speed is displayed. This parameter is used by the Automatic Retarder Control to prevent the engine from overspeeding. If you have an approved password, you can change this parameter.
- **Throttle Position:** When you scroll to this option, the throttle position is displayed.
- **Coolant Temperature:** When you scroll to this option, the coolant temperature is displayed.

- **Coolant Flow:** When you scroll to this option, the amount of coolant flow is displayed.
- **Boost Pressure:** When you scroll to this option, the boost pressure is displayed.
- **Atmospheric Pressure:** When you scroll to this option, the atmospheric pressure is displayed.
- **Turbo Inlet Pressure:** When you scroll to this option, the turbo inlet pressure is displayed.
- **Oil Pressure (Antilock brake system):** When you scroll to this option, the absolute engine oil pressure is displayed.
- **Oil Pressure:** When you scroll to this option, the gauge engine oil pressure is displayed.
- **Fuel Temperature:** When you scroll to this option, the fuel temperature is displayed.

SYSTEMS TESTS

SYSTEM SELF TEST

If you select this option, the monitoring system will initiate the self-test feature. The self test feature is like the functional test that occurs when you turn the start switch from the OFF position to the ON position.

SYSTEM INFORMATION

MONITORING SYSTEM

- **Software Part Number:** When you scroll to this option, the software part number is displayed.
- **ECM Part Number:** When you scroll to this option, the ECM part number is displayed.
- **Software Release Date:** When you scroll to this option, the software release date is displayed.
- **Software Description:** When you scroll to this option, the software description is displayed.

ENGINE

- **ECM Serial Number:** When you scroll to this option, the ECM serial number is displayed.
- **Software Part Number:** When you scroll to this option, the software part number is displayed.
- **Software Release Date:** When you scroll to this option, the software release date is displayed.
- **Software Description:** When you scroll to this option, the software description is displayed.

- **Engine Serial Number:** When you scroll to this option, the engine serial number is displayed.

TATTLETALE

- **Full Tattletale Readout:** When you select this option, all indicators and gauges will display the maximum values reached during operation.
- **Engine Coolant Temperature:** When you select this option, all indicators and will display the maximum values reached during operation. The engine coolant temperature gauge will also show the maximum value reached during operation.
- **Tachometer:** When you select this option, all indicators will display the maximum values reached during operation. The tachometer will also show the maximum value reached during operation.
- **Fuel Level:** When you select this option, all indicators will display the maximum values reached during operation. The fuel level gauge will also show the minimum value reached during operation.
- **Clear:** If you have an approved password, you can clear the maximum values stored by the monitoring system.

Engine Diagnostics

i01463253

Self-Diagnostics

i00863835

SMCS Code: 1000; 1900; 1901; 1902

The electronic control module has some self-diagnostic ability. When an electronic problem with an input or an output is detected, a diagnostic code is generated. This indicates the specific problem with the circuitry.

Diagnostic codes are also generated when an abnormal engine operating condition is detected. For example, a diagnostic code will be generated if the low oil pressure alarm is activated. In this case, the diagnostic code indicates the symptom of a problem. This type of diagnostic code is called an event. An event is triggered by the detection of an abnormal engine operating condition.

A diagnostic code which represents a problem that currently exists is called an active code.

A diagnostic code that is stored in memory is called a logged code. Always service active codes prior to servicing logged codes. Logged codes may include the following categories:

- Intermittent problems
- Recorded events
- Performance history

Logged codes may not indicate that a repair is needed. The problems may have been repaired since the logging of the code. Logged codes may be helpful to troubleshoot intermittent problems.

Diagnostic Lamp

SMCS Code: 1000; 1900; 1901; 1902; 7451

The "DIAGNOSTIC" lamp is used to indicate the existence of an active fault by flashing codes.

When the ignition switch is first turned on, the "DIAGNOSTIC" lamp will go through the following procedure:

- The "DIAGNOSTIC" lamp will come on and the "DIAGNOSTIC" lamp will remain on for five seconds. This checks the operation of the lamp.
- The "DIAGNOSTIC" lamp will turn off.
- The "DIAGNOSTIC" lamp will come on again and the "DIAGNOSTIC" lamp will flash codes for any active diagnostic codes. Not all diagnostic codes have a unique flash code.
- The "DIAGNOSTIC" lamp will turn off for five seconds.
- The "DIAGNOSTIC" lamp repeats all active diagnostic codes.

A fault diagnostic code will remain active until the problem is repaired. The electronic control module will continue flashing the flash code at five second intervals until the problem is repaired.

i03855688

Diagnostic Flash Code Retrieval

SMCS Code: 1000; 1900; 1901; 1902

"Diagnostic" Lamp

Use the "DIAGNOSTIC" lamp or a Caterpillar electronic service tool to determine the diagnostic flash code. Not all diagnostic codes have a unique flash code.

Note: Flash codes should only be used to indicate the nature of a diagnostic condition. Do not use flash codes to perform detailed troubleshooting.

Use the following procedure to retrieve the diagnostic codes if the application is equipped with an engine DIAGNOSTIC lamp:

1. The "DIAGNOSTIC" lamp will flash in order to indicate a two-digit code. The sequence of flashes represents the system diagnostic message. Each digit of the two-digit code is determined by counting the number of flashes. The lamp flashes at a rate of two times per second. The lamp will pause for one second between digits. The lamp will pause for two seconds between codes.
2. Turn the start/run key to the ON position. The engine does not need to be started in order to view codes. The engine does not need to be running while the start/run switch is in the ON position.

The "DIAGNOSTIC" lamp blinks on and off at five second intervals.

- When the start/run key is in the ON position, the lamp is checked for proper operation. If there are any active codes except for Code 34, the codes are displayed at this time.

Note: The "DIAGNOSTIC" lamp will illuminate for five seconds. The lamp will stay on if there is an active diagnostic code.

3. Active diagnostic codes will always be flashed. There is no toggle switch that will shut off the lamp.

Table 2 indicates the potential effect on the engine performance with active flash codes. Table 2 also forms a list of Electronic diagnostic codes and descriptions.

Possible Performance Effect of Active Diagnostic Codes

Table 2

Possible Performance Effect of Active Diagnostic Codes							
Flash Code	CID-FMI Code	SPN ⁽¹⁾ -FMI Code	Description of Code	Engine Misfires	Low Power	Reduced Engine Speed	Engine Shutdown

(continued)

(Table 2, contd)

Possible Performance Effect of Active Diagnostic Codes							
Flash Code	CID-FMI Code	SPN ⁽¹⁾ -FMI Code	Description of Code	Engine Misfires	Low Power	Reduced Engine Speed	Engine Shutdown
N/A	111-02	111-02	Engine Coolant Level Sensor Loss of Signal	X	X	X	
	1835-03	1387-03	Auxiliary Pressure Sensor open/short to +batt				
	1835-04	1387-04	Auxiliary Pressure Sensor short to ground				
	1836-03	441-03	Auxiliary Temperature Sensor open/short to +batt				
	1836-04	441-04	Auxiliary Temperature Sensor short to ground				
	2417-05	626-05	Ether Injection Control Solenoid current low				
	2417-06	626-06	Ether Injection Control Solenoid current high				
13	174-03	174-03	Fuel Temperature open/short to +batt				
	174-04	174-04	Fuel Temperature short to ground				
21	41-03	678-03	8 Volt DC Supply short to +batt				
	41-04	678-04	8 Volt DC Supply short to ground				
	262-03	620-03	5 Volt Sensor DC Power Supply				
		1079-03	short to +batt				
	262-04	620-04	5 Volt Sensor DC Power Supply				
		1079-04	short to ground				
24	100-03	100-03	Engine Oil Pressure open/short to +batt				
	100-04	100-04	Engine Oil Pressure short to ground				
	100-10	100-10	Engine Oil Pressure abnormal rate of change				

(continued)

(Table 2, contd)

Possible Performance Effect of Active Diagnostic Codes							
Flash Code	CID-FMI Code	SPN ⁽¹⁾ -FMI Code	Description of Code	Engine Misfires	Low Power	Reduced Engine Speed	Engine Shutdown
25	102-03	102-03	Boost Pressure Sensor short to +batt		X		
	1785-03		Intake Manifold Pressure Sensor voltage high				
	102-04	102-04	Boost Pressure Sensor short to ground		X		
	1785-04		Intake Manifold Pressure Sensor voltage low				
	102-10	102-10	Boost Pressure Sensor abnormal rate of change		X		
	1785-10		Intake Manifold Pressure Sensor abnormal rate of change				
26	274-03	108-03	Atmospheric Pressure open/short to +batt				
	274-04	108-04	Atmospheric Pressure short to ground				
27	110-03	110-03	Engine Coolant Temperature open/short to +batt	X	X	X	
	110-04	110-04	Engine Coolant Temperature short to ground	X	X	X	
28	91-13	91-13	Throttle Position calibration required		X	X	
32	91-08	91-08	Throttle Position signal abnormal		X	X	
34	190-08	190-08	Engine Speed signal abnormal	X			X ⁽²⁾
	342-08	723-08	Secondary Engine Speed signal abnormal		X		X ⁽¹⁾
37	94-03	94-03	Fuel Pressure open/short to +batt				
	94-04	94-04	Fuel Pressure short to ground				

(continued)

(Table 2, contd)

Possible Performance Effect of Active Diagnostic Codes							
Flash Code	CID-FMI Code	SPN ⁽¹⁾ -FMI Code	Description of Code	Engine Misfires	Low Power	Reduced Engine Speed	Engine Shutdown
38	172-03	105-03	Intake Manifold Air Temp open/short to +batt				
	172-04	105-04	Intake Manifold Air Temp short to ground				
42	261-13	637-13	Engine Timing calibration required	X	X	X	
51	168-00	168-00	System Voltage high				
	168-01	168-01	System Voltage low	X			X
	168-02	168-02	System Voltage intermittent/erratic	X			X
56	253-02	631-02	Personality Module mismatch				X ⁽³⁾
	268-02	630-02	Check Programmable Parameters				
58	247-09	639-09	J1939 Data Link communications				
71	001-05	651-05	Cylinder # 1 Injector open circuit	X	X		
	001-06	651-06	Cylinder # 1 Injector short	X	X		
72	002-05	652-05	Cylinder # 2 Injector open circuit	X	X		
	002-06	652-06	Cylinder # 2 Injector short	X	X		
73	003-05	653-05	Cylinder # 3 Injector open circuit	X	X		
	003-06	653-06	Cylinder # 3 Injector short	X	X		
74	004-05	654-05	Cylinder # 4 Injector open circuit	X	X		
	004-06	654-06	Cylinder # 4 Injector short	X	X		
75	005-05	655-05	Cylinder # 5 Injector open circuit	X	X		
	005-06	655-06	Cylinder # 5 Injector short	X	X		

(continued)

(Table 2, contd)

Possible Performance Effect of Active Diagnostic Codes							
Flash Code	CID-FMI Code	SPN ⁽¹⁾ -FMI Code	Description of Code	Engine Misfires	Low Power	Reduced Engine Speed	Engine Shutdown
76	006-05	656-05	Cylinder # 6 Injector open circuit	X	X		
	006-06	656-06	Cylinder # 6 Injector short	X	X		
77	007-05	657-05	Cylinder # 7 Injector open circuit	X	X		
	007-06	657-06	Cylinder # 7 Injector short	X	X		
78	008-05	658-05	Cylinder # 8 Injector open circuit	X	X		
	008-06	658-06	Cylinder # 8 Injector short	X	X		
79	009-05	659-05	Cylinder # 9 Injector open circuit	X	X		
	009-06	659-06	Cylinder # 9 Injector short	X	X		
80	010-05	660-05	Cylinder # 10 Injector open circuit	X	X		
	010-06	660-06	Cylinder # 10 Injector short	X	X		
81	011-05	661-05	Cylinder # 11 Injector open circuit	X	X		
	011-06	661-06	Cylinder # 11 Injector short	X	X		
82	012-05	662-05	Cylinder # 12 Injector open circuit	X	X		
	012-06	662-06	Cylinder # 12 Injector short	X	X		

⁽¹⁾ Suspect Parameter Number

⁽²⁾ The engine will shut down if both speed/timing sensors are lost.

⁽³⁾ Fuel injection will not occur and the engine will not start.

Event Codes

The ECM can log events. Events refer to engine operating conditions such as low oil pressure or high coolant temperature. Table 3 is a cross-reference for event codes. Logged events usually indicate a mechanical problem instead of an electronic system problem.

Table 3

Cross-Reference for Event Codes			
Flash Codes	EID Codes	SPN-FMI Codes	Description of Code

(continued)

(Table 3, contd)

Cross-Reference for Event Codes			
Flash Codes	EID Codes	SPN-FMI Codes	Description of Code
N/A	E443 ⁽¹⁾	1387-15	High Auxiliary Pressure Warning
		1387-16	High Auxiliary Pressure Derate
		1387-00	High Auxiliary Pressure Shutdown
	E445 ⁽¹⁾	441-15	High Auxiliary Temperature Warning
		441-16	High Auxiliary Temperature Derate
		441-00	High Auxiliary Temperature Shutdown
35	E362 ⁽¹⁾	190-15	Engine Overspeed Warning
		190-00	Engine Overspeed Shutdown
46	E360 ⁽¹⁾	100-17	Low Engine Oil Pressure Warning
		100-18	Low Engine Oil Pressure Derate
		100-01	Low Engine Oil Pressure Shutdown
61	E361 ⁽¹⁾	110-15	High Engine Coolant Temperature Warning
		110-16	High Engine Coolant Temperature Derate
		110-00	High Engine Coolant Temperature Shutdown
62	E2143 ⁽¹⁾	111-17	Low Engine Coolant Level Warning
		111-18	Low Engine Coolant Level Derate
		111-01	Low Engine Coolant Level Shutdown
63	E539 ⁽¹⁾	94-15	High Fuel Pressure Warning

(continued)

(Table 3, contd)

Cross-Reference for Event Codes			
Flash Codes	EID Codes	SPN-FMI Codes	Description of Code
64	E539 ⁽¹⁾	105-15	High Intake Manifold Air Temperature Warning
		105-00	High Intake Manifold Air Temperature Shutdown
65	E363 ⁽¹⁾	174-15	High Fuel Temperature Warning
		174-16	High Fuel Temperature Derate
		174-00	High Fuel Temperature Shutdown

⁽¹⁾ Caterpillar Electronic Technician (ET) will display the number 1, 2, or 3 after the event code in order to designate a warning, a derate, or a shutdown.

For further information or assistance for repairs, consult an authorized Caterpillar dealer.

I03840813

Fault Logging

SMCS Code: 1000; 1900; 1901; 1902

The system provides the capability of Fault Logging. When the Electronic Control Module (ECM) generates an active diagnostic code, the code will be logged in the memory of the ECM. The codes that have been logged in the memory of the ECM can be retrieved with Caterpillar electronic service tools. The codes that have been logged can be cleared with Caterpillar electronic service tools. The codes that have been logged in the memory of the ECM will be automatically cleared from the memory after 100 hours. The following faults cannot be cleared from the memory of the ECM without using a factory password: overspeed, low engine oil pressure, and high engine coolant temperature.

i02784364

Engine Operation with Active Diagnostic Codes

SMCS Code: 1000; 1900; 1901; 1902

If the diagnostic lamp starts to flash codes during normal engine operation, the system has identified a situation that is not within the specification. Use Caterpillar electronic service tools to check the active diagnostic codes.

Note: If the customer has selected "DERATE" and if there is a low oil pressure condition, the Electronic Control Module (ECM) will limit the engine power until the problem is corrected. If the oil pressure is within the normal range, the engine may be operated at the rated speed and load. However, maintenance should be performed as soon as possible. Refer to Operation and Maintenance Manual, "Diagnostic Flash Code Retrieval" for more information on flash codes.

The active diagnostic code should be investigated. The cause of the problem should be corrected as soon as possible. Operation of the engine and performance of the engine can be limited as a result of the active diagnostic code that is generated. If the cause of the active diagnostic code is repaired and there is only one active diagnostic code, the diagnostic lamp will turn off.

i01456915

Engine Operation with Intermittent Diagnostic Codes

SMCS Code: 1000; 1900; 1901; 1902

If the diagnostic lamp starts to flash codes during normal engine operation and the diagnostic lamp shuts off, an intermittent fault may have occurred. If a fault has occurred, the fault will be logged into the memory of the Electronic Control Module (ECM).

In most cases, it is not necessary to stop the engine because of an intermittent code. However, the operator should retrieve the logged fault codes and the operator should reference the appropriate information in order to identify the nature of the event. The operator should log any observation that could have caused the lamp to light.

- Low power
- Limits of the engine speed
- Excessive smoke, etc

This information can be useful to help troubleshoot the situation. The information can also be used for future reference. For more information on diagnostic codes, refer to the Troubleshooting Guide for this engine.

i02918535

Configuration Parameters

SMCS Code: 1000; 1900; 1901; 1902

Customer specified parameters that will enhance the fuel efficiency and the operator's convenience can be programmed into the Electronic Control Module (ECM). Some parameters may affect engine operation. This may lead to complaints from the operator about power or about performance. The following engine related parameters may be programmed by the customer by using Caterpillar electronic service tools in order to influence the operation of the engine:

Customer password

This parameter allows the customer to lock out certain parameters by entering a password. Customer passwords must be used to unlock any parameters that are protected by customer passwords before the parameter can be changed. Factory passwords are required if this password is lost.

Customer Passwords

- First Password _____
- Second Password _____

Power Rating (hp at rpm) _____

Rating Selection (A-E) _____

PTO Governor Parameters

- PTO Engine Speed Ramp Rate _____ rpm/sec

Engine Parameters

- Top Engine Limit (TEL) at 100 percent load (If Applicable) _____
- Torque Limit _____
- High Idle (If Applicable) _____
- Low Idle _____
- Intermediate Speed _____

Engine Monitoring Mode

- "OFF" _____
- "Warning" _____
- "Warning/Derate" _____
- "Warning/Derate/Shutdown" _____
- "Coolant Level Sensor Enable/Disable" _____
- "Fuel Pressure Sensor Enable/Disable" _____
- "Inlet Manifold Air Temperature Sensor Enable/Disable" _____

Equipment ID

Maintenance Indicator

- Manual-Hours
- Auto-Hours
- Manual-Fuel
- Auto-Fuel

Auxiliary Pressure

- High Warning Set Point _____

Auxiliary Temperature

- High Warning Set Point _____

The customer specified parameters can be changed as often as needed. Password protection is provided so that the customer can change the parameters. The customer can authorize someone else to change the parameters. Ensure that a record of the parameters is kept in the Operation and Maintenance Manual. For detailed instructions on programming the engine for optimum performance and for optimum fuel economy, consult your Caterpillar dealer.

Engine Starting

I02048636

Before Starting Engine

SMCS Code: 1000; 1400; 1450

Perform the required daily maintenance and other periodic maintenance before the engine is started. Inspect the engine compartment. This inspection can help prevent major repairs at a later date. Refer to the Operation and Maintenance Manual, "Maintenance Interval Schedule" for more information.

- For the maximum service life of the engine, make a thorough inspection before the engine is started. Look for the following items: oil leaks, coolant leaks, loose bolts, and trash buildup. Remove trash buildup and arrange for repairs, as needed.
- Inspect the cooling system hoses for cracks and for loose clamps.
- Inspect the alternator and accessory drive belts for cracks, breaks, and other damage.
- Inspect the wiring for loose connections and for worn wires or frayed wires.
- Check the fuel supply. Drain water from the water separator (if equipped). Open the fuel supply valve.

NOTICE

All valves in the fuel return line must be open before and during engine operation to help prevent high fuel pressure. High fuel pressure may cause filter housing failure or other damage.

If the engine has not been started for several weeks, fuel may have drained from the fuel system. Air may have entered the filter housing. Also, when fuel filters have been changed, some air pockets will be trapped in the engine. In these instances, prime the fuel system. Refer to the Operation and Maintenance Manual, "Fuel System - Prime" for more information on priming the fuel system.

WARNING

Engine exhaust contains products of combustion which may be harmful to your health. Always start and operate the engine in a well ventilated area and, if in an enclosed area, vent the exhaust to the outside.

- Do not start the engine or move any of the controls if there is a "DO NOT OPERATE" warning tag or similar warning tag attached to the start switch or to the controls.
- Ensure that the areas around the rotating parts are clear.
- All of the guards must be put in place. Check for damaged guards or for missing guards. Repair any damaged guards. Replace damaged guards and/or missing guards.
- Disconnect any battery chargers that are not protected against the high current drain that may be created. Check electrical cables and check the battery for poor connections and for corrosion.
- Reset all of the shutoffs or alarm components.
- Check the engine lubrication oil level. Maintain the oil level between the "ADD" mark and the "FULL" mark on the oil level gauge.
- Check the coolant level. Observe the coolant level in the coolant recovery tank (if equipped). Maintain the coolant level to the "FULL" mark on the coolant recovery tank.
- If the engine is not equipped with a coolant recovery tank maintain the coolant level within 13 mm (0.5 inch) of the bottom of the filler pipe. If the engine is equipped with a sight glass, maintain the coolant level in the sight glass.
- Observe the air cleaner service indicator (if equipped). Service the air cleaner when the yellow diaphragm enters the red zone, or when the red piston locks in the visible position.
- Ensure that any driven equipment has been disengaged. Minimize electrical loads or remove any electrical loads.

I03954049

Cold Weather Starting

SMCS Code: 1000; 1250; 1450; 1453; 1456; 1900

Refer to the Owners Manual of the OEM for your type of controls. Use the following procedure in order to start the engine.

⚠ WARNING

DO NOT USE ETHER (starting fluids) unless specifically instructed to do so. If the engine is equipped with an Air Inlet Heater (electrically or fuel ignited manifold heater), **DO NOT** use ether (starting fluids) at any time. The use could result in engine damage and/or personal injury.

Startability will be improved at temperatures below 10°C (50°F) from the use of a cylinder block coolant heater or from other means that are used to heat the crankcase oil. Some engine applications use a jacket water heater to improve startability. The jacket water heater will help reduce white smoke and misfire during start-up in cold weather.

NOTICE

When using ether (starting fluid), follow the manufacturer's instructions carefully, use it sparingly and spray it only while cranking the engine. Excessive ether can cause piston and ring damage. Use ether (starting fluid) for cold weather starting purposes only.

For engines that are not equipped with an Air Inlet Heater, use ether when temperatures are below 0°C (32°F). If the engine is equipped with an injection system for starting fluid, crank the engine. Depress the ether switch for 3 seconds. Additional injections may be necessary in order to start the engine.

Note: If the engine has not been run for several weeks, fuel may have drained. Air may have moved into the filter housing. Also, when fuel filters have been changed, some air will be left in the filter housing. Refer to the Operation and Maintenance Manual, "Fuel System - Prime" (Maintenance Section) for more information on priming the fuel system.

NOTICE

Do not engage the starting motor when flywheel is turning. Do not start the engine under load.

If the engine fails to start within 30 seconds, release the starter switch or button and wait two minutes to allow the starting motor to cool before attempting to start the engine again.

1. Place the transmission in NEUTRAL. Disengage the flywheel clutch in order to allow the engine to start faster and reduce the drain on the battery.
2. Turn the ignition switch to the ON position.

The "CHECK ENGINE/DIAGNOSTIC" lamp will flash while the engine is cranking. The lamp should turn off after proper engine oil pressure is achieved. If the lamp fails to flash, notify your authorized Caterpillar dealer. If the lamp continues to flash, the Electronic Control Module (ECM) has detected a problem in the system. Refer to the Operation and Maintenance Manual, "Diagnostic Flash Code Retrieval" for more information.

3. Push the start button or turn the ignition switch to the START position in order to crank the engine.

Do not push down or hold the throttle down while the engine is cranked. The system will automatically provide the correct amount of fuel that is needed to start the engine.

4. If the engine fails to start within 30 seconds, release the start button, or the ignition switch. Wait for 2 minutes in order to allow the starting motor to cool before attempting to start the engine again.

NOTICE

Oil pressure should rise within 15 seconds after the engine starts. Do not increase engine speed until the oil pressure gauge indicates normal. If oil pressure is not indicated on the gauge within 15 seconds, **DO NOT** operate the engine. **STOP** the engine, investigate and correct the cause.

Note: The "CHECK ENGINE/DIAGNOSTIC" lamp may come on after the engine is started. If the lamp comes on, the Electronic Control Module (ECM) has detected a problem with the system. Refer to the Operation and Maintenance Manual, "Diagnostic Flash Code Retrieval" for more information.

5. Allow the engine to idle for approximately 3 minutes. Idle the engine until the water temperature gauge has begun to rise. Check all gauges during the warm-up period.

Note: The oil pressures and fuel pressures should be in the normal range on the instrument panel. Do not apply a load to the engine or increase engine rpm until the oil pressure gauge indicates at least normal pressure. Inspect the engine for leaks and/or unusual noises.

101646219

Starting the Engine

SMCS Code: 1000; 1450

This start procedure may be used for all engines that are not equipped with an Air Inlet Heater regardless of ambient temperature.

Refer to the Owner's Manual of the OEM for your type of controls. Use the following procedure to start the engine.

1. Place the transmission in NEUTRAL. Disengage the flywheel clutch in order to allow the engine to start faster. This also reduces the draining of the battery.
2. Turn the keyswitch to the ON position.

The "CHECK ENGINE/DIAGNOSTIC" lamp will flash while the engine is cranking. The lamp should turn off after proper engine oil pressure is achieved. If the lamp fails to flash, notify your authorized Caterpillar dealer. If the lamp continues to flash, the Electronic Control Module (ECM) has detected a problem in the system. Refer to the Operation and Maintenance Manual, "Diagnostic Flash Code Retrieval" (Operation Section) for more information.

3. Push the start button or turn the keyswitch to the START position in order to crank the engine.

Do not push down or hold the throttle down while the engine is cranked. The system will automatically provide the correct amount of fuel that is needed to start the engine.

4. If the engine fails to start within 30 seconds, release the start button, or the keyswitch. Wait for two minutes in order to allow the starting motor to cool before attempting to start the engine again.

Note: The "CHECK ENGINE/DIAGNOSTIC" lamp may come on after the engine is started. If this occurs, the ECM has detected a problem with the system. Refer to the Operation and Maintenance Manual, "Diagnostic Flash Code Retrieval" (Operation Section) for more information.

NOTICE

Oil pressure should rise within 15 seconds after the engine starts. Do not increase engine rpm until the oil pressure gauge indicates normal. If oil pressure is not indicated on the gauge within 15 seconds, DO NOT operate the engine. STOP the engine, investigate and correct the cause.

5. Allow the engine to idle for approximately three minutes. Idle the engine until the water temperature gauge has begun to rise. Check all gauges during the warm-up period.

Note: Oil pressures and fuel pressures should be in the normal range on the instrument panel. Do not apply a load to the engine or increase engine rpm until the oil pressure gauge indicates at least normal pressure. Inspect the engine for leaks and/or unusual noises.

i04471308

Starting with Jump Start Cables

SMCS Code: 1000; 1401; 1402; 1900

WARNING

Improper jump start cable connections can cause an explosion resulting in personal injury.

Prevent sparks near the batteries. Sparks could cause vapors to explode. Do not allow jump start cable ends to contact each other or the engine.

If the installation is not equipped with a backup battery system, an external electrical source may be necessary to start the engine.

NOTICE

Using a battery source with the same voltage as the electric starting motor. Use ONLY equal voltage for jump starting. The use of higher voltage will damage the electrical system.

Do not reverse the battery cables. The alternator can be damaged. Attach the negative cable last and remove first.

When using an external electrical source to start the engine, turn the generator set control switch to the "OFF" position. Turn all electrical accessories OFF before attaching the jump-start cables.

Ensure that the main power switch is in the OFF position before attaching the jump-start cables to the engine being started.

1. Turn the start switch to the OFF position. Turn off all accessories.
2. Connect one positive end of the jump-start cable to the positive cable terminal of the discharged battery. Connect the other positive end of the jump-start cable to the positive cable terminal of the electrical source.
3. Connect one negative end of the jump-start cable to the negative cable terminal of the electrical source. Connect the other negative end of the jump-start cable to the engine block or to the chassis ground. This procedure helps to prevent potential sparks from igniting combustible gases that are produced by some batteries.
4. Start the engine.

5. Immediately after the stalled engine is started, disconnect the jump-start cables in reverse order.

Note: If there is a problem with the alternator or the battery charger, the engine will not continue to run after starting, unless the power to the engine control module is supplied by a separate source.

i01646248

After Starting Engine

SMCS Code: 1000

Note: In temperatures from 0 to 60°C (32 to 140°F), the warm-up time is approximately three minutes. In temperatures below 0°C (32°F), additional warm-up time may be required.

Note: Ensure that the self test for the monitoring system (if equipped) is completed before operating the engine under load.

When the engine idles during warm-up, observe the following conditions:

- Check for any fluid or for any air leaks at idle rpm and at one-half full rpm (no load on the engine) before operating the engine under load. This is not possible in some applications.
- Operate the engine at low idle until all systems achieve operating temperatures. Check all gauges during the warm-up period.

Note: Gauge readings should be observed and the data should be recorded frequently while the engine is operating. Comparing the data over time will help to determine normal readings for each gauge. Comparing data over time will also help detect abnormal operating developments. Significant changes in the readings should be investigated.

Engine Operation

i01646252

Engine Operation

SMCS Code: 1000

Proper operation and maintenance are key factors in obtaining the maximum life and economy of the engine. If the directions in the Operation and Maintenance Manual are followed, costs can be minimized and engine service life can be maximized.

The time that is needed for the engine to reach normal operating temperature can be less than the time taken for a walk-around inspection of the engine.

The engine can be operated at the rated rpm after the engine is started and after the engine reaches operating temperature. The engine will reach normal operating temperature sooner during a low engine speed (rpm) and during a low power demand. This procedure is more effective than idling the engine at no load. The engine should reach operating temperature in a few minutes.

Gauge readings should be observed and the data should be recorded frequently while the engine is operating. Comparing the data over time will help to determine normal readings for each gauge. Comparing data over time will also help detect abnormal operating developments. Significant changes in the readings should be investigated.

Engaging the Driven Equipment

i01646335

SMCS Code: 1000

1. Operate the engine at one-half of the rated rpm, when possible.
2. Engage the driven equipment without a load on the equipment, when possible.

Interrupted starts put excessive stress on the drive train. Interrupted starts also waste fuel. To get the driven equipment in motion, engage the clutch smoothly with no load on the equipment. This method should produce a start that is smooth and easy. The engine rpm should not increase and the clutch should not slip.

3. Ensure that the ranges of the gauges are normal when the engine is operating at one-half of the rated rpm. Ensure that all gauges operate properly.
4. Increase the engine rpm to the rated rpm. Always increase the engine rpm to the rated rpm before the load is applied.
5. Apply the load. Begin operating the engine at low load. Check the gauges and equipment for proper operation. After normal oil pressure is reached and the temperature gauge begins to move, the engine may be operated at full load. Check the gauges and equipment frequently when the engine is operated under load.

Extended operation at low idle or at reduced load may cause increased oil consumption and carbon buildup in the cylinders. This carbon buildup results in a loss of power and/or poor performance.

101136207

Fuel Conservation Practices

SMCS Code: 1000; 1250

The efficiency of the engine can affect the fuel economy. Caterpillar's design and technology in manufacturing provides maximum fuel efficiency in all applications. Follow the recommended procedures in order to attain optimum performance for the life of the engine.

- Avoid spilling fuel.

Fuel expands when the fuel is warmed up. The fuel may overflow from the fuel tank. Inspect fuel lines for leaks. Repair the fuel lines, as needed.

- Be aware of the properties of the different fuels. Use only the recommended fuels.
- Avoid unnecessary idling.

Shut off the engine rather than idle for long periods of time.

- Observe the service indicator frequently. Keep the air cleaner elements clean.
- Ensure that the turbochargers are operating correctly so that the proper air/fuel ratio is maintained. Clean exhaust indicates proper functioning.
- Maintain a good electrical system.

One faulty battery cell will overwork the alternator. This will consume excess power and excess fuel.

- Ensure that the belts are properly adjusted. The belts should be in good condition.
- Ensure that all of the connections of the hoses are tight. The connections should not leak.
- Ensure that the driven equipment is in good working order.
- Cold engines consume excess fuel. Utilize heat from the jacket water system and the exhaust system, when possible. Keep cooling system components clean and keep cooling system components in good repair. Never operate the engine without water temperature regulators. All of these items will help maintain operating temperatures.

Cold Weather Operation

i01646447

Radiator Restrictions

SMCS Code: 1353; 1396

Caterpillar discourages the use of airflow restriction devices that are mounted in front of radiators. Airflow restriction can cause the following conditions:

- High exhaust temperatures
- Power loss
- Excessive fan usage
- Reduction in fuel economy

If an airflow restriction device must be used, the device should have a permanent opening directly in line with the fan hub. A centered opening that is directly in line with the fan hub is specified in order to prevent an interrupted airflow on the fan blades. Interrupted airflow on the fan blades could cause a fan failure.

Caterpillar recommends a warning device for the inlet manifold temperature and/or the installation of an inlet air temperature gauge. The warning device for the inlet manifold temperature should be set at 75 °C (167 °F). The inlet manifold air temperature should not exceed 75 °C (167 °F). Temperatures that exceed this limit can cause power loss and potential engine damage.

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Fuel and the Effect from Cold Weather

SMCS Code: 1000; 1250; 1280

The following fuels are the grades that are available for Caterpillar engines:

- No. 1
- No. 2
- Blend of No. 1 and No. 2

No. 2 diesel fuel is the most commonly used fuel. Either No. 1 diesel fuel or a blend of No. 1 and No. 2 is best suited for cold weather operation.

Quantities of No. 1 diesel fuel are limited. No. 1 diesel fuels are usually available during the months of the winter in the colder climates. During cold weather operation, if No. 1 diesel fuel is not available, use No. 2 diesel fuel, if necessary.

There are three major differences between No. 1 and No. 2 diesel fuel. No. 1 diesel fuel has the following properties:

- Lower cloud point
- Lower pour point
- Lower rating of kJ (BTU) per unit volume of fuel

When No. 1 diesel fuel is used, a decrease in power and in fuel efficiency may be noticed. Other operating effects should not be experienced.

The cloud point is the temperature when a cloud of wax crystals begins to form in the fuel. These crystals can cause the fuel filters to plug. The pour point is the temperature when diesel fuel will thicken. The diesel fuel becomes more resistant to flow through fuel pumps and through fuel lines.

Be aware of these values when diesel fuel is purchased. Anticipate the average ambient temperature of the area. Engines that are fueled in one climate may not operate well if the engines are moved to another climate. Problems can result due to changes in temperature.

Before troubleshooting for low power or for poor performance in the winter, check the type of fuel that is being used.

When No. 2 diesel fuel is used the following components provide a means of minimizing problems in cold weather:

- Starting aids
- Engine oil pan heaters
- Engine coolant heaters
- Fuel heaters
- Fuel line insulation

For more information on cold weather operation, see Special Publication, SEBU5898, "Cold Weather Recommendations".

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Fuel Related Components in Cold Weather

SMCS Code: 1000; 1250; 1280

Fuel Tanks

Condensation can form in partially filled fuel tanks. Top off the fuel tanks after operating the engine.

Fuel tanks should contain some provision for draining water and sediment from the bottom of the tanks. Some fuel tanks use supply pipes that allow water and sediment to settle below the end of the fuel supply pipe.

Some fuel tanks use supply lines that take fuel directly from the bottom of the tank. If the engine is equipped with this system, regular maintenance of the fuel system filter is important.

Drain the water and sediment from any fuel storage tank at the following intervals:

- Weekly
- Oil changes
- Refueling of the fuel tank

This will help prevent water and/or sediment from being pumped from the fuel storage tank and into the engine fuel tank.

Fuel Filters

NOTICE

Do not fill the fuel filters with fuel before installing them. The fuel would not be filtered and could be contaminated. Contaminated fuel will cause accelerated wear to fuel system parts.

NOTICE

In order to maximize fuel system life and prevent premature wear out from abrasive particles in the fuel, a two micron absolute high efficiency fuel filter is required for all Caterpillar Hydraulic Electronic Unit Injectors. Caterpillar High Efficiency Fuel Filters meet these requirements. Consult your Caterpillar dealer for the proper part numbers.

These engines are equipped with a primary filter/water separator. The primary filter/water separator must use a 10 micron filter to a 15 micron filter. The filters are becoming more critical as fuel injection pressures increase to 209 MPa (30000 psi) and higher psi. For more information on priming the fuel system, see the Operation and Maintenance Manual, "Fuel System - Prime" topic (Maintenance Section).

Fuel Heaters

Note: Always follow the precautions in this Operation and Maintenance Manual, "Fire Prevention and Explosion Prevention".

Fuel heaters help to prevent fuel filters from plugging in cold weather due to waxing. A fuel heater should be installed in order for the fuel to be heated before the fuel enters the primary fuel filter.

Select a fuel heater that is mechanically simple, yet adequate for the application. The fuel heater should also help to prevent overheating of the fuel. High fuel temperatures reduce engine performance and the availability of engine power. Choose a fuel heater with a large heating surface. The fuel heater should be practical in size. Small heaters can be too hot due to the limited surface area.

Disconnect the fuel heater in warm weather.

Note: Fuel heaters that are controlled by the water temperature regulator or self-regulating fuel heaters should be used with this engine. Fuel heaters that are not controlled by the water temperature regulator can heat the fuel in excess of 65° C (149° F). A loss of engine power can occur if the fuel supply temperature exceeds 37° C (100° F).

Note: Heat exchanger type fuel heaters should have a bypass provision in order to prevent overheating of the fuel in warm weather operation.

For further information on fuel heaters, consult your Caterpillar dealer.

Engine Stopping

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Manual Stop Procedure

i04315380

SMCS Code: 1000; 7418

NOTICE

Stopping the engine immediately after it has been working under load can result in overheating and accelerated wear of the engine components.

If the engine has been operating at high rpm and/or high loads, run at low idle for at least three minutes to reduce and stabilize internal engine temperature before stopping the engine.

Avoiding hot engine shutdowns will maximize turbocharger shaft and bearing life.

Note: Individual applications have different control systems. Ensure that the shutoff procedures are understood. Use the following general guidelines in order to stop the engine.

1. Remove the load from the engine so that the engine has no more than 30% power.
2. Run the engine at the programmed low idle speed for at least 3 minutes.
3. After the cool down period, turn the start switch to the OFF position.

After Stopping Engine

SMCS Code: 1000

Note: Before you check the engine oil, do not operate the engine for at least 10 minutes in order to allow the engine oil to return to the oil pan.

- Check the crankcase oil level. Maintain the oil level between the "ADD" mark and the "FULL" mark on the oil level gauge.
- If necessary, perform minor adjustments. Repair any leaks and tighten any loose bolts.
- Note the service hour meter reading. Perform the maintenance that is in the Operation and Maintenance Manual, "Maintenance Interval Schedule".
- Fill the fuel tank in order to help prevent accumulation of moisture in the fuel. Do not overfill the fuel tank.

NOTICE

Only use antifreeze/coolant mixtures recommended in the Coolant Specifications that are in the Operation and Maintenance Manual. Failure to do so can cause engine damage.

- Allow the engine to cool. Check the coolant level. Maintain the cooling system at 13 mm (0.5 inch) from the bottom of the pipe for filling.
- If freezing temperatures are expected, check the coolant for proper antifreeze protection. The cooling system must be protected against freezing to the lowest expected outside temperature. Add the proper coolant/water mixture, if necessary.
- Perform all required periodic maintenance on all driven equipment. This maintenance is outlined in the instructions from the OEM.

Maintenance Section

Refill Capacities

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Refill Capacities

SMCS Code: 1000; 1348; 1395; 7560

Refer to this Operation and Maintenance Manual, "Fluid Recommendations" for information about the fluids which are acceptable for this engine.

Note: Refer to Special Publication, SEBU6251, "Caterpillar Commercial Diesel Engine Fluids Recommendations" for additional information.

Lubricant Refill Capacity

The refill capacities for the engine crankcase reflect the approximate capacity of the crankcase or sump plus standard oil filters. Auxiliary oil filter systems will require additional oil. Refer to the OEM specifications for the capacity of the auxiliary oil filter.

Table 4

C27 and C32 Industrial Engines Approximate Refill Capacities		
Compartment or System	Liters	Quarts
Engine Crankcase	68	72

Coolant Refill Capacity

To maintain the cooling system, the total cooling system capacity must be known. The capacity of the total cooling system will vary. The capacity will depend on the size of the radiator (capacity). Table 5 should be completed by the customer for the maintenance of the cooling system.

Table 5

C27 and C32 Industrial Engines Approximate Refill Capacities		
Compartment or System	Liters	Quarts
Engine Only	55	58
External System (OEM) ⁽¹⁾		
Total Cooling System ⁽²⁾		

⁽¹⁾ The External System includes a radiator or an expansion tank with the following components: heat exchanger, aftercooler, and piping. Refer to the Caterpillar specifications or the OEM specifications and enter the capacity for the External System in this row.

⁽²⁾ The Total Cooling System includes the capacity for the engine plus the capacity for the external system. Enter the total in this row.

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Fluid Recommendations

SMCS Code: 1280; 1348; 1395; 7560

NOTICE

Every attempt is made to provide accurate, up-to-date information. By the use of this document, you agree that Caterpillar Inc. is not responsible for errors or omissions.

NOTICE

These recommendations are subject to change without prior notice. Contact your Caterpillar dealer for the most up to date recommendations.

Refer to Special Publication, SEBU6251, "Cat Commercial Diesel Engine Fluids Recommendations" for additional information.

Refer to this Operation and Maintenance Manual, "Severe Service Application" for information about operating an engine in a severe service application.

Note: Instructions for the installation of the filter are printed on the side of each Cat spin-on filter. For filters that are not Cat filters, refer to the installation instructions that are provided by the supplier of the filter.

Diesel Engine Oil

Cat DEO (Diesel Engine Oil)

Due to significant variations in the quality and in the performance of commercially available oils, Caterpillar makes the following recommendations:

- Cat DEO-ULS (Diesel Engine Oil Ultra Low Sulfur) (SAE 5W-40)

- Cat DEO-ULS (Diesel Engine Oil Ultra Low Sulfur) (SAE 10W-30)
- Cat DEO-ULS (Diesel Engine Oil Ultra Low Sulfur) (SAE 15W-40)

Engine Oil

Cat oils have been developed and tested in order to provide the full performance and life that has been designed and built into Cat engines.

Cat DEO-ULS or oils that meet the Cat ECF-3 specification and the API CJ-4 are required for use in the applications listed below. Cat DEO-ULS and oils meeting Cat ECF-3 specification and the API CJ-4 and ACEA E9 oil categories have been developed with limited sulfated ash, phosphorus, and sulfur. These chemical limits are designed to maintain the expected aftertreatment devices life, performance, and service interval. If oils meeting the Cat ECF-3 specification and the API CJ-4 specifications are not available, oils meeting ACEA E9 may be used. ACEA E9 oils meet the chemical limits designed to maintain aftertreatment device life. ACEA E9 oils are validated using some but not all ECF-3 and API CJ-4 standard engine performance tests. Consult your oil supplier when considering use of an oil that is not Cat ECF-3 or API CJ-4 qualified.

Failure to meet the listed requirements will damage aftertreatment-equipped engines and can negatively impact the performance of the aftertreatment devices. The Diesel Particulate Filter (DPF) will plug sooner and require more frequent DPF ash service intervals.

Typical aftertreatment systems include the following:

- Diesel Particulate Filters (DPF)
- Diesel Oxidation Catalysts (DOC)
- Selective Catalytic Reduction (SCR)
- Lean NOx Traps (LNT)

Other systems may apply.

Table 6

Lubricant Viscosities for Ambient Temperatures						
Compartment or System	Oil Type and Performance Requirements	Oil Viscosities	°C		°F	
			Min	Max	Min	Max
Engine Crankcase	Cat DEO-ULS Cold Weather	SAE 0W-40	-40	40	-40	104
	Cat DEO-ULS	SAE 10W-30	-18	40	0	104
	Cat DEO-ULS	SAE 15W-40	-9.5	50	15	122

NOTICE

Oil Renewal systems should not be used in engines equipped with aftertreatment systems. Reduced life or damage to the aftertreatment may occur.

S-O-S Services Oil Analysis**NOTICE**

These recommendations are subject to change without prior notice. Contact your Caterpillar dealer for the most up to date recommendations.

Caterpillar has developed a maintenance tool that evaluates oil degradation, the maintenance management also detects the early signs of wear on internal components. The Cat tool for oil analysis is called S-O-S Oil Analysis and the tool is part of the S-O-S Services program. S-O-S Oil Analysis divides oil analysis into four categories:

- Component wear rate
- Oil condition
- Oil contamination
- Identification of oil

These four types of analysis are used to monitor the condition of your equipment. The four types of analysis will also help you identify potential problems. A properly administered S-O-S Oil Analysis program will reduce repair costs and the program will lessen the impact of downtime.

The S-O-S Oil Analysis program uses a wide range of tests to determine the condition of the oil and the lubricated compartment. Guidelines that are based on experience and a correlation to failures have been established for these tests. Exceeding one or more of these guidelines could indicate serious fluid degradation or a pending component failure. A trained person at your Cat dealership should make the final analysis.

NOTICE

Always use a designated pump for oil sampling, and use a separate designated pump for coolant sampling. Using the same pump for both types of samples may contaminate the samples that are being drawn. This contaminate may cause a false analysis and an incorrect interpretation that could lead to concerns by both dealers and customers.

Refer to Special Publication, SEBU6251, "Cat Commercial Diesel Engine Fluids Recommendations" in order to obtain additional information about S-O-S Services oil analysis. You can also contact your local Cat dealer in order to obtain additional information about the S-O-S Services Oil Analysis program.

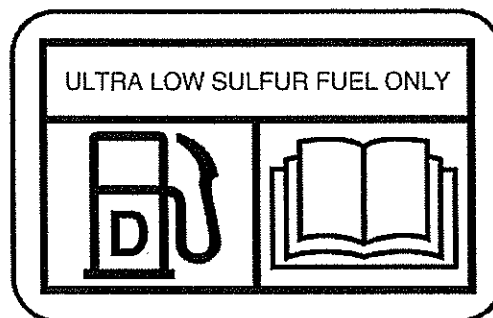
Diesel Fuel Recommendations

Illustration 19

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NACD Film

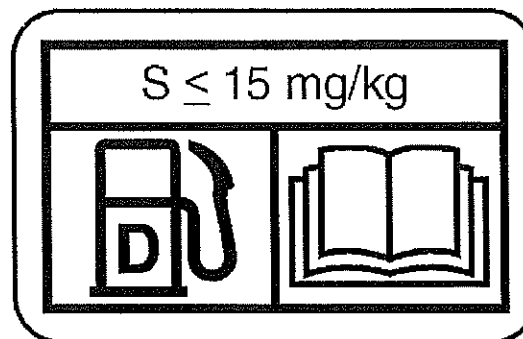


Illustration 20

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EAME Film

Diesel fuel must meet "Cat Specification for Distillate Fuel" and the latest versions of "ASTM D975" or "EN 590" in order to ensure optimum engine performance. Refer to Special Publication, SEBU6251, "Cat Commercial Diesel Engine Fluids Recommendations" for the latest fuel information and for Cat fuel specification. This manual may be found on the Web at Safety.Cat.com.

NOTICE

Ultra Low Sulfur Diesel (ULSD) fuel 0.0015 percent (≤ 15 ppm (mg/kg)) sulfur is required by regulation for use in engines certified to nonroad Tier 4 standards (U.S. EPA Tier 4 certified) and that are equipped with exhaust aftertreatment systems.

European ULSD 0.0010 percent (≤ 10 ppm (mg/kg)) sulfur fuel is required by regulation for use in engines certified to European nonroad Stage IIIB and newer standards and are equipped with exhaust aftertreatment systems.

Misfueling with fuels of higher sulfur level can have the following negative effects:

- Shorten the time interval between aftertreatment device service intervals (cause the need for more frequent service intervals)
- Adversely impact the performance and life of aftertreatment devices (cause loss of performance)
- Reduce regeneration intervals of aftertreatment devices
- Reduce engine efficiency and durability.
- Increase the wear.
- Increase the corrosion.
- Increase the deposits.
- Lower fuel economy
- Shorten the time period between oil drain intervals (more frequent oil drain intervals).
- Increase overall operating costs.

Failures that result from the use of improper fuels are not Cat factory defects. Therefore the cost of repairs would not be covered by a Cat warranty.

Cat does not require the use of ULSD in off road and machine applications that are not Tier 4/Stage IIIB certified engines. ULSD is not required in engines that are not equipped with after treatment devices. For Tier 4/Stage IIIB/Stage IV certified engines always follow operating instructions. Fuel tank inlet labels are installed in order to ensure that the correct fuels are used.

Refer to Special Publication, SEBU6251, "Cat Commercial Diesel Engine Fluids Recommendations" for more details about fuels, lubricants, and Tier 4 requirements. This manual may be found on the Web at Safety.Cat.com.

Lubricating Grease

NOTICE

These recommendations are subject to change without prior notice. Contact your Caterpillar dealer for the most up to date recommendations.

Cat provides various greases that vary in performance from a moderate performance to high performance. Cat greases service the entire line of Cat products in the wide variety of climates throughout the world. From this variety of Cat grease products, you can find a Cat grease that will meet or exceed the performance requirements of most engines.

The performance requirements of your engine must be determined before you select any Cat grease. Consult the recommendations for greases that are made by the OEM for the equipment. Then, consult with your Cat dealer for a list of greases that have the performance specifications and the available sizes of containers.

Note: Always choose grease that meets or exceeds the recommendations that are specified by the equipment manufacturer for the application.

If it is necessary to choose a single grease to use for all of the equipment at one site, always choose a grease that meets or exceeds the requirements of the most demanding application. Remember that the products which barely meet the minimum performance requirements can be expected to produce the minimum lives of your parts. False economy is being used if a grease is purchased with the lowest cost as the only consideration. Instead, use the grease that yields the lowest total operating cost. This cost should be based on an analysis that includes the costs of parts, labor, downtime, and the cost of the amount of grease that is required.

Note: Purge all of the old grease from a joint before you change from one type of grease to another type of grease. Some greases are not chemically compatible with other greases. Consult your supplier in order to determine if the greases are compatible.

If you are not certain that the old grease is compatible with the new grease, purge the old grease from the system before applying the new grease.

Note: All Cat greases are chemically compatible with each other. Mixing of Cat greases does not result in an adverse chemical reaction. However, mixing of Cat greases may result in reduced performance.

Non-Cat commercial greases are as a group second choice greases. Within this grouping of second choice greases, there are tiered levels of performance. For more information, refer to Special Publication, SEBU6251, "Cat Commercial Diesel Engines Fluids Recommendations".

Coolant

NOTICE

These recommendations are subject to change without prior notice. Contact your Caterpillar dealer for the most up to date recommendations.

NOTICE

Never add coolant to an overheated engine. Engine damage could result. Allow the engine to cool first.

NOTICE

Frequently check the specific gravity of the coolant for proper freeze protection or for anti-boil protection.

NOTICE

Never operate an engine without water temperature regulators in the cooling system. Water temperature regulators help to maintain the engine coolant at the proper operating temperature. Cooling system problems can develop without water temperature regulators.

The following two coolants are used in Cat Diesel Engines:

Preferred – Cat ELC (Extended Life Coolant) or a commercial extended life coolant that meets the Cat Engine Coolant -1 (EC-1) specification.

Acceptable – Cat DEAC (Diesel Engine Antifreeze/Coolant) or a commercial heavy-duty coolant that meets "ASTM D4985", or "ASTM D6210" specifications

Note: Cat DEAC does not require a treatment with a Supplemental Coolant Additive (SCA) at the initial fill. However, a commercial heavy-duty coolant that only meets the "ASTM D4985" specification will require a treatment with an SCA at the initial fill. A commercial heavy-duty coolant that meets the "ASTM D6210" specification will not require a treatment with an SCA at the initial fill. Read the label or the instructions that are provided by the manufacturer of the commercial heavy-duty coolant.

Note: These coolants will require a treatment with a supplemental coolant additive on a maintenance basis.

Table 7

Service Life Before Flushing and Before Refilling	
Coolant	Service Life ⁽¹⁾
Cat ELC	12,000 hours, or 6 years
Commercial coolant that meets the Cat EC-1 specification	6000 hours, or 6 years
Cat DEAC	3000 hours, or 3 years
Commercial Heavy-Duty Coolant that meets "ASTM D4985" or "ASTM D6210"	3000 hours, or 1 year

⁽¹⁾ Use the interval that occurs first.

Note: Add the Cat ELC Extender at the halfway point of the coolant change interval.

Note: These coolant change intervals are only possible with annual S-O-S Services Level 2 coolant sampling and analysis.

S-O-S Services Coolant Analysis

Table 8

Recommended Interval		
Type of Coolant	Level 1	Level 2
DEAC	Every 500 Hours ⁽¹⁾ ⁽²⁾	Every 2000 Hours or Yearly ⁽¹⁾⁽³⁾
ELC	Optional ⁽³⁾	Yearly ⁽³⁾

⁽¹⁾ This interval is recommended for the sampling of all conventional heavy-duty coolant.

⁽²⁾ This interval is also recommended for the sampling of a commercial coolant that meets the Cat (Engine Coolant specification - 1) requirement.

⁽³⁾ The Level 2 coolant analysis should be performed sooner if a problem is suspected or identified.

Testing the engine coolant is important to ensure that the engine is protected from internal cavitation and from corrosion. The analysis also tests the ability of the coolant to protect the engine from boiling and from freezing. The S-O-S Coolant Analysis can be performed at your Cat dealer. Cat S-O-S Coolant Analysis is the best way to monitor the condition of your coolant and your cooling system. S-O-S Coolant Analysis is a program that is based on periodic samples.

NOTICE

Always use a designated pump for oil sampling, and use a separate designated pump for coolant sampling. Using the same pump for both types of samples may contaminate the samples that are being drawn. This contaminate may cause a false analysis and an incorrect interpretation that could lead to concerns by both dealers and customers.

For more information, refer to Special Publication, SEBU6251, "Cat Commercial Diesel Engines Fluids Recommendations"

Maintenance Recommendations

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System Pressure Release

SMCS Code: 1250; 1300; 1350; 5050

Coolant System

 WARNING

Pressurized system: Hot coolant can cause serious burn. To open cap, stop engine, wait until radiator is cool. Then loosen cap slowly to relieve the pressure.

To relieve the pressure from the coolant system, turn off the engine. Allow the cooling system pressure cap to cool. Remove the cooling system pressure cap slowly in order to relieve pressure.

Fuel System

To relieve the pressure from the fuel system, turn off the engine.

High Pressure Fuel Lines (If Equipped)

 WARNING

Contact with high pressure fuel may cause fluid penetration and burn hazards. High pressure fuel spray may cause a fire hazard. Failure to follow these inspection, maintenance and service instructions may cause personal injury or death.

The high pressure fuel lines are the fuel lines that are between the high pressure fuel pump and the high pressure fuel manifold and the fuel lines that are between the fuel manifold and cylinder head. These fuel lines are different from fuel lines on other fuel systems.

This is because of the following differences:

- The high pressure fuel lines are constantly charged with high pressure.
- The internal pressures of the high pressure fuel lines are higher than other types of fuel system.

Before any service or repair is performed on the engine fuel lines, perform the following tasks:

1. Stop the engine.
2. Wait for ten minutes.

Do not loosen the high pressure fuel lines in order to remove air pressure from the fuel system.

Engine Oil

To relieve pressure from the lubricating system, turn off the engine.

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Welding on Engines with Electronic Controls

SMCS Code: 1000

NOTICE

Because the strength of the frame may decrease, some manufacturers do not recommend welding onto a chassis frame or rail. Consult the OEM of the equipment or your Caterpillar dealer regarding welding on a chassis frame or rail.

Proper welding procedures are necessary in order to avoid damage to the engine's ECM, sensors, and associated components. When possible, remove the component from the unit and then weld the component. If removal of the component is not possible, the following procedure must be followed when you weld on a unit that is equipped with a Caterpillar Electronic Engine. The following procedure is considered to be the safest procedure to weld on a component. This procedure should provide a minimum risk of damage to electronic components.

NOTICE

Do not ground the welder to electrical components such as the ECM or sensors. Improper grounding can cause damage to the drive train, the bearings, hydraulic components, electrical components, and other components.

Do not ground the welder across the centerline of the package. Improper grounding could cause damage to the bearings, the crankshaft, the rotor shaft, and other components.

Clamp the ground cable from the welder to the component that will be welded. Place the clamp as close as possible to the weld. This will help reduce the possibility of damage.

Note: Perform the welding in areas that are free from explosive hazards.

1. Stop the engine. Turn the switched power to the OFF position.
2. Disconnect the negative battery cable from the battery. If a battery disconnect switch is provided, open the switch.
3. Disconnect the J1/P1 and J2/P2 connectors from the ECM. Move the harness to a position that will not allow the harness to accidentally move back and make contact with any of the ECM pins.

Note: If electrical/electronic components are used as a ground for the welder, or electrical/electronic components are located between the welder ground and the weld, current flow from the welder could severely damage the component.

5. Protect the wiring harness from welding debris and spatter.
6. Use standard welding practices to weld the materials.

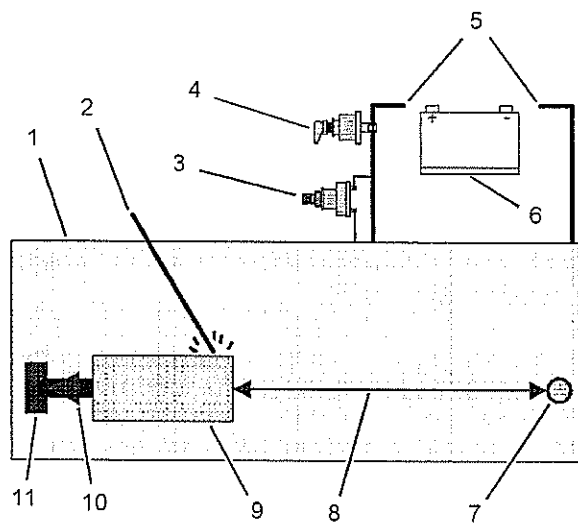


Illustration 21

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Use the example above. The current flow from the welder to the ground clamp of the welder will not cause damage to any associated components.

- (1) Engine
- (2) Welding electrode
- (3) Keyswitch in the OFF position
- (4) Battery disconnect switch in the open position
- (5) Disconnected battery cables
- (6) Battery
- (7) Electrical/Electronic component
- (8) Minimum distance between the component that is being welded and any electrical/electronic component
- (9) The component that is being welded
- (10) Current path of the welder
- (11) Ground clamp for the welder

4. Connect the welding ground cable directly to the part that will be welded. Place the ground cable as close as possible to the weld in order to reduce the possibility of welding current damage to bearings, hydraulic components, electrical components, and ground straps.

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Maintenance Interval Schedule

SMCS Code: 1000; 4450; 7500

Ensure that all safety information, warnings, and instructions are read and understood before any operation or any maintenance procedures are performed.

The user is responsible for the performance of maintenance, including all adjustments. The user is also responsible for the use of proper lubricants, fluids, filters, and the replacement of components due to normal wear and aging. Failure to adhere to proper maintenance intervals and procedures may result in diminished performance of the product and/or accelerated wear of components.

Use mileage, fuel consumption, service hours, or calendar time, **WHICH EVER OCCURS FIRST**, in order to determine the maintenance intervals. Products that operate in severe operating conditions may require more frequent maintenance.

Note: Before each consecutive interval is performed, all maintenance from the previous interval must be performed.

When Required

Battery or Battery Cable - Disconnect	56
Engine Storage Procedure - Check	74
Fuel System - Prime	75

Daily

Coolant Level - Check	61
Driven Equipment - Check	65
Engine Air Cleaner Service Indicator - Inspect	68
Engine Air Precleaner - Check/Clean	69
Engine Oil Level - Check	70
Fuel System Primary Filter/Water Separator - Drain	77
Fuel Tank Water and Sediment - Drain	78
Walk-Around Inspection	91

Initial 20 to 40 Service Hours

Belts - Inspect/Adjust/Replace	56
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Initial 250 Service Hours

Engine Valve Lash - Check	74
Engine Valve Rotators - Inspect	74
Fuel Injector - Inspect/Adjust	75

Every 250 Service Hours

Aftercooler Core - Clean/Test	55
Belts - Inspect/Adjust/Replace	56
Coolant Sample (Level 1) - Obtain	62

Cooling System Supplemental Coolant Additive (SCA) - Test/Add	63
Engine Oil Sample - Obtain	71
Engine Oil and Filter - Change	71
Engine Protective Devices - Check	73
Fan Drive Bearing - Lubricate	75
Fuel System Secondary Filter - Replace	77
Hoses and Clamps - Inspect/Replace	80
Radiator - Clean	89

Initial 500 Hours (for New Systems, Refilled Systems, and Converted Systems)

Coolant Sample (Level 2) - Obtain	62
---	----

Every 500 Service Hours

Fuel System Primary Filter (Water Separator) Element - Replace	76
--	----

Every 500 Service Hours or 3 Months

Battery Electrolyte Level - Check	55
---	----

Every 1500 Service Hours

Engine Crankcase Breather - Clean	69
Fumes Disposal Filter Element - Replace	79

Every 2000 Service Hours

Fuel Injector - Inspect/Adjust	75
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Every Year

Coolant Sample (Level 2) - Obtain	62
Engine Air Cleaner Element (Dual Element) - Inspect/Clean/Replace	66

Every 3000 Service Hours

Crankshaft Vibration Damper - Inspect	65
Engine - Clean	65
Engine Mounts - Inspect	70
Engine Valve Rotators - Inspect	74

Every 3000 Service Hours or 3 Years

Coolant (DEAC) - Change	57
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Every 4500 Service Hours

Engine Speed/Timing Sensor - Clean/Inspect	73
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Every 5000 Service Hours

Starting Motor - Inspect	89
Turbocharger - Inspect	90
Water Pump - Inspect	92

Every 6000 Service Hours or 3 Years

Coolant (ELC) - Change	59
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Every 6000 Service Hours or 6 Years

Coolant Extender (ELC) - Add	60
Engine Speed/Timing Sensor - Clean/Inspect	73

Every 8000 Service Hours

Fan Drive Bearing - Replace	75
-----------------------------------	----

Every 19 000 L (5000 US gal) of Fuel or 250 Service Hours

Engine Air Cleaner Element (Dual Element) - Inspect/Clean/Replace	66
--	----

PM Level 2 - Every 83 250 L (22 000 US gal) of Fuel or 2000 Service Hours or 1 Year

Engine Valve Lash - Check	74
---------------------------------	----

Every 228 000 L (60 000 US gal) of Fuel or 3000 Service Hours

Coolant Temperature Regulator - Replace	63
---	----

Every 605 670 L (160 000 US gal) of Fuel or 9000 Service Hours

Overhaul (Top End)	84
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Every 1 211 330 L (320 000 US gal) of Fuel or 18 000 Service Hours

Overhaul (Major)	82
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Overhaul

Overhaul Considerations	85
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Aftercooler Core - Clean/Test

SMCS Code: 1064-070; 1064-081

Note: Adjust the frequency of cleaning according to the effects of the operating environment.

Inspect the aftercooler for these items: damaged fins, corrosion, dirt, grease, insects, leaves, oil, and other debris. Clean the aftercooler, if necessary.

For air-to-air aftercoolers, use the same methods that are used for cleaning radiators.

WARNING

Personal injury can result from air pressure.

Personal injury can result without following proper procedure. When using pressure air, wear a protective face shield and protective clothing.

Maximum air pressure at the nozzle must be less than 205 kPa (30 psi) for cleaning purposes.

Pressurized air is the preferred method for removing loose debris. Direct the air in the opposite direction of the air flow from the fan. Hold the nozzle approximately 6 mm (.25 inch) away from the fins. Slowly move the air nozzle in a direction that is parallel with the tubes. This will remove debris that is between the tubes.

Pressurized water may also be used for cleaning. The maximum water pressure for cleaning purposes must be less than 275 kPa (40 psi). Use pressurized water in order to soften mud. Clean the core from both sides.

Use a degreaser and steam for removal of oil and grease. Clean both sides of the core. Wash the core with detergent and hot water. Thoroughly rinse the core with clean water.

Inspect the fins for damage. Bent fins may be opened with a "comb".

Note: If parts of the aftercooler system are repaired or replaced, a leak test is highly recommended.

Inspect these items for good condition: welds, mounting brackets, air lines, connections, clamps, and seals. Make repairs, if necessary.

Battery Electrolyte Level - Check

SMCS Code: 1401-535-FLV

When the engine is not run for long periods of time or when the engine is run for short periods, the batteries may not fully recharge. Ensure a full charge in order to help prevent the battery from freezing.

WARNING

All lead-acid batteries contain sulfuric acid which can burn the skin and clothing. Always wear a face shield and protective clothing when working on or near batteries.

1. Remove the filler caps. Maintain the electrolyte level to the "FULL" mark on the battery.

If the addition of water is necessary, use distilled water. If distilled water is not available use clean water that is low in minerals. Do not use artificially softened water.

2. Check the condition of the electrolyte with the 245-5829 Coolant Battery Tester Refractometer.
3. Keep the batteries clean.

Clean the battery case with one of the following cleaning solutions:

- A mixture of 0.1 kg (0.2 lb) of baking soda and 1 L (1 qt) of clean water
- A mixture of 0.1 L (0.11 qt) of ammonia and 1 L (1 qt) of clean water

Thoroughly rinse the battery case with clean water.

Use a fine grade of sandpaper to clean the terminals and the cable clamps. Clean the items until the surfaces are bright or shiny. DO NOT remove material excessively. Excessive removal of material can cause the clamps to not fit properly. Coat the clamps and the terminals with 5N-5561 Silicone Lubricant, petroleum jelly or MPGM.

i01857537

Battery or Battery Cable - Disconnect

SMCS Code: 1401; 1402-029

WARNING

The battery cables or the batteries should not be removed with the battery cover in place. The battery cover should be removed before any servicing is attempted.

Removing the battery cables or the batteries with the cover in place may cause a battery explosion resulting in personal injury.

1. Switch the engine to the OFF position. Turn the ignition switch (if equipped) to the OFF position and remove the key and all electrical loads.
2. Disconnect the negative battery terminal at the battery that goes to the start switch. Ensure that the cable cannot contact the terminal.
3. Tape the leads in order to help prevent accidental starting.
4. Proceed with necessary system repairs. Reverse the steps in order to reconnect all of the cables.

i02304925

Belts - Inspect/Adjust/Replace

SMCS Code: 1357-025; 1357-040; 1357-510

Inspection

Belt tension should be checked initially between the first 20 to 40 hours of engine operation.

After the initial check, the belt tension should be checked at Every PM Level 1 or Three Months.

To maximize the engine performance, inspect the belts for wear and for cracking. Replace belts that are worn or damaged.

For applications that require multiple drive belts, replace the belts in matched sets. Replacing only one belt of a matched set will cause the new belt to carry more load because the older belt is stretched. The additional load on the new belt could cause the new belt to break.

If the belts are too loose, vibration causes unnecessary wear on the belts and pulleys. Loose belts may slip enough to cause overheating.

If the belts are too tight, unnecessary stresses are placed on the pulley bearings and on the belts. This may shorten the service life of the components.

Remove the belt guard. Inspect the condition and adjustment of the alternator belts and accessory drive belts (if equipped).

To check the belt tension, apply 110 N (25 lb ft) of force midway between the pulleys. A correctly adjusted belt will deflect 9 mm (0.35 inch) to 15 mm (0.59 inch).

If the belt does not require replacement or adjustment, install the belt guard. If the belt requires adjustment or replacement, perform the following procedure to adjust the belt tension.

- If the engine is equipped with a refrigerant compressor (air conditioner), the belt for the fan drive, the alternator, and the accessories will have an automatic belt tensioner.
- If the engine is not equipped with a refrigerant compressor, the alternator is used to adjust the belt tension.

Adjustment

Alternator Belt

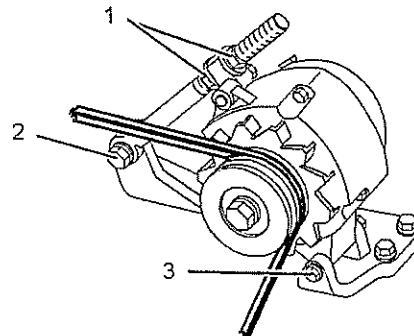


Illustration 22

g01154344

Typical alternator mounting

- (1) Adjusting nuts
- (2) Mounting bolt
- (3) Mounting bolts

1. Slightly loosen mounting bolt (2) and mounting bolt (3). Slightly loosen adjusting nut (1).
2. Move the pulley in order to adjust the belt tension.

3. Tighten the following: adjusting nuts (1), mounting bolt (2), and mounting bolt (3). Refer to the Specifications, SENR3130 in order to locate the proper torques.

4. Install the belt guard.

If new belts are installed, check the belt tension again after 30 minutes of engine operation at the rated rpm.

i03841934

Coolant (DEAC) - Change

SMCS Code: 1350-070; 1395-044

Clean the cooling system and flush the cooling system before the recommended maintenance interval if the following conditions exist:

- The engine overheats frequently.
- Foaming is observed.
- The oil has entered the cooling system and the coolant is contaminated.
- The fuel has entered the cooling system and the coolant is contaminated.

NOTICE

Use of commercially available cooling system cleaners may cause damage to cooling system components. Use only cooling system cleaners that are approved for Caterpillar engines.

Note: Inspect the water pump and the water temperature regulator after the cooling system has been drained. This is a good opportunity to replace the water pump, the water temperature regulator and the hoses, if necessary.

Drain



WARNING

Pressurized System: Hot coolant can cause serious burns. To open the cooling system filler cap, stop the engine and wait until the cooling system components are cool. Loosen the cooling system pressure cap slowly in order to relieve the pressure.

1. Stop the engine and allow the engine to cool. Loosen the cooling system filler cap slowly in order to relieve any pressure. Remove the cooling system filler cap.

2. Open the cooling system drain valve (if equipped). If the cooling system is not equipped with a drain valve, remove one of the drain plugs.

Note: If equipped, be sure to drain the heater and any related supply and return lines.

Allow the coolant to drain.

NOTICE

Dispose of used engine coolant properly or recycle. Various methods have been proposed to reclaim used coolant for reuse in engine cooling systems. The full distillation procedure is the only method acceptable by Caterpillar to reclaim the used coolant.

For information regarding the disposal and the recycling of used coolant, consult your Caterpillar dealer or consult Caterpillar Dealer Service Tool Group:

Outside Illinois: 1-800-542-TOOL

Inside Illinois: 1-800-541-TOOL

Canada: 1-800-523-TOOL

Flush

1. Flush the cooling system with clean water in order to remove any debris.
2. Close the drain valve (if equipped). Clean the drain plugs. Install the drain plugs. Refer to the Specifications Manual, SENR3130, "Torque Specifications" for more information on the proper torques.

NOTICE

Fill the cooling system no faster than 19 L (5 US gal) per minute to avoid air locks.

3. Fill the cooling system with a mixture of clean water and Caterpillar Fast Acting Cooling System Cleaner. Add 0.5 L (1 pint) of cleaner per 15 L (4 US gal) of the cooling system capacity. Install the cooling system filler cap.
4. Start and run the engine at low idle for a minimum of 30 minutes. The coolant temperature should be at least 82 °C (180 °F).

NOTICE

Improper or incomplete rinsing of the cooling system can result in damage to copper and other metal components.

To avoid damage to the cooling system, make sure to completely flush the cooling system with clear water. Continue to flush the system until all signs of the cleaning agent are gone.

5. Stop the engine and allow the engine to cool. Loosen the cooling system filler cap slowly in order to relieve any pressure. Remove the cooling system filler cap. Open the drain valve (if equipped) or remove the cooling system drain plugs. Allow the water to drain. Flush the cooling system with clean water. If equipped, be sure to flush the heater and any related supply and return lines. Close the drain valve (if equipped). Clean the drain plugs. Install the drain plugs. Refer to the Specifications Manual, SENR3130, "Torque Specifications" for more information on the proper torques.

Cooling Systems with Heavy Deposits or Plugging

Note: For the following procedure to be effective, there must be some active flow through the cooling system components.

1. Flush the cooling system with clean water in order to remove any debris.

Note: If equipped, be sure to flush the heater and any related supply and return lines.

2. Close the drain valve (if equipped). Clean the drain plugs. Install the drain plugs. Refer to the Specifications Manual, SENR3130, "Torque Specifications" for more information on the proper torques.

NOTICE

Fill the cooling system no faster than 19 L (5 US gal) per minute to avoid air locks.

3. Fill the cooling system with a mixture of clean water and Caterpillar Fast Acting Cooling System Cleaner. Add 0.5 L (1 pint) of cleaner per 3.8 to 7.6 L (1 to 2 US gal) of the cooling system capacity. Install the cooling system filler cap.
4. Start and run the engine at low idle for a minimum of 90 minutes. The coolant temperature should be at least 82 °C (180 °F).

NOTICE

Improper or incomplete rinsing of the cooling system can result in damage to copper and other metal components.

To avoid damage to the cooling system, make sure to completely flush the cooling system with clear water. Continue to flush the system until all signs of the cleaning agent are gone.

5. Stop the engine and allow the engine to cool. Loosen the cooling system filler cap slowly in order to relieve any pressure. Remove the cooling system filler cap. Open the drain valve (if equipped) or remove the cooling system drain plugs. Allow the water to drain. Flush the cooling system with clean water. Close the drain valve (if equipped). Clean the drain plugs. Install the drain plugs. Refer to the Specifications Manual, SENR3130, "Torque Specifications" for more information on the proper torques.

Fill

NOTICE

Fill the cooling system no faster than 19 L (5 US gal) per minute to avoid air locks.

1. Fill the cooling system with an antifreeze/coolant solution. Refer to the Operation and Maintenance Manual, "Refill Capacities and Recommendations" topic (Maintenance Section) for more information on cooling system specifications. Do not install the cooling system filler cap.
2. Start and run the engine at low idle. Increase the engine rpm to 1500 rpm. Run the engine at high idle for one minute in order to purge the air from the cavities of the engine block. Stop the engine.
3. Check the coolant level. Maintain the coolant level within 13 mm (0.5 inch) below the bottom of the pipe for filling. Maintain the coolant level within 13 mm (0.5 inch) to the proper level on the sight glass (if equipped).

4. Clean the cooling system filler cap. Inspect the gasket that is on the cooling system filler cap. If the gasket that is on the cooling system filler cap is damaged, discard the old cooling system filler cap and install a new cooling system filler cap. If the gasket that is on the cooling system filler cap is not damaged, perform a pressure test. A 9S-8140 Pressurizing Pump is used to perform the pressure test. The correct pressure for the cooling system filler cap is stamped on the face of the cooling system filler cap. If the cooling system filler cap does not retain the correct pressure, install a new cooling system filler cap.
5. Start the engine. Inspect the cooling system for leaks and for proper operating temperature.

i05185194

Coolant (ELC) - Change

SMCS Code: 1350-070; 1395-044

Clean the cooling system and flush the cooling system before the recommended maintenance interval if the following conditions exist:

- The engine overheats frequently.
- Foaming is observed.
- The oil has entered the cooling system and the coolant is contaminated.
- The fuel has entered the cooling system and the coolant is contaminated.

Note: When the cooling system is cleaned, only clean water is needed when the ELC is drained and replaced.

Note: Inspect the water pump and the water temperature regulator after the cooling system has been drained. This is a good opportunity to replace the water pump, the water temperature regulator, and the hoses, if necessary.

Drain



WARNING

Pressurized System: Hot coolant can cause serious burns. To open the cooling system filler cap, stop the engine and wait until the cooling system components are cool. Loosen the cooling system pressure cap slowly in order to relieve the pressure.

1. Stop the engine and allow the engine to cool. Loosen the cooling system filler cap slowly in order to relieve any pressure. Remove the cooling system filler cap.
2. Open the cooling system drain valve (if equipped). If the cooling system is not equipped with a drain valve, remove the cooling system drain plugs.

Allow the coolant to drain.

NOTICE

Dispose of used engine coolant properly or recycle. Various methods have been proposed to reclaim used coolant for reuse in engine cooling systems. The full distillation procedure is the only method acceptable by Caterpillar to reclaim the used coolant.

NOTICE

Care must be taken to ensure that fluids are contained during performance of inspection, maintenance, testing, adjusting and repair of the product. Be prepared to collect the fluid with suitable containers before opening any compartment or disassembling any component containing fluids.

Refer to Special Publication, NENG2500, "Caterpillar Dealer Service Tool Catalog" or refer to Special Publication, PECJ0003, "Caterpillar Shop Supplies and Tools Catalog" for tools and supplies suitable to collect and contain fluids on Caterpillar products.

Dispose of all fluids according to local regulations and mandates.

For information regarding the disposal and the recycling of used coolant, consult your Caterpillar dealer or consult Caterpillar Dealer Service Tool Group:

Outside Illinois: 1-800-542-TOOL
Inside Illinois: 1-800-541-TOOL
Canada: 1-800-523-TOOL

Flush

1. Flush the cooling system with clean water in order to remove any debris.
2. Close the drain valve (if equipped). Clean the drain plugs. Install the drain plugs. Refer to the Specifications Manual, SENR3130, "Torque Specifications" for more information on the proper torques.

NOTICE

Fill the cooling system no faster than 19 L (5 US gal) per minute to avoid air locks.

3. Fill the cooling system with clean water. Install the cooling system filler cap.
4. Start and run the engine at low idle until the temperature reaches 49 to 66 °C (120 to 150 °F).
5. Stop the engine and allow the engine to cool. Loosen the cooling system filler cap slowly in order to relieve any pressure. Remove the cooling system filler cap. Open the drain valve (if equipped) or remove the cooling system drain plugs. Allow the water to drain. Flush the cooling system with clean water. Close the drain valve (if equipped). Clean the drain plugs. Install the drain plugs. Refer to the Specifications Manual, SENR3130, "Torque Specifications" for more information on the proper torques.

Fill

NOTICE

Fill the cooling system no faster than 19 L (5 US gal) per minute to avoid air locks.

1. Fill the cooling system with Extended Life Coolant (ELC). Refer to this Operation and Maintenance Manual, "Fluid Recommendations" for more information on cooling system specifications. Do not install the cooling system filler cap.
2. Start and run the engine at low idle. Increase the engine rpm to high idle. Run the engine at high idle for 1 minute in order to purge the air from the cavities of the engine block. Stop the engine.
3. Check the coolant level. Maintain the coolant level within 13 mm (0.5 inch) below the bottom of the pipe for filling. Maintain the coolant level within 13 mm (0.5 inch) to the proper level on the sight glass (if equipped).
4. Clean the cooling system filler cap. Inspect the gasket that is on the cooling system filler cap. Only install the used filler cap if the gasket is not damaged. Use a 9S-8140 Pressurizing Pump to pressure test a reinstalled cooling system filler cap. The correct pressure for the cooling system filler cap is stamped on the face of the cooling system filler cap. If the cooling system filler cap does not retain the correct pressure, install a new cooling system filler cap.
5. Start the engine. Inspect the cooling system for leaks and for proper operating temperature.

i04745732

Coolant Extender (ELC) - Add

SMCS Code: 1352-544-NL

Cat ELC (Extended Life Coolant) does not require the frequent additions of any supplemental cooling additives which are associated with the present conventional coolants. The Cat ELC Extender will only be added one time.

NOTICE

Use only Cat Extended Life Coolant (ELC) Extender with Cat ELC.

Do NOT use conventional supplemental coolant additive (SCA) with Cat ELC. Mixing Cat ELC with conventional coolants and/or conventional SCA reduces the Cat ELC service life.

Check the cooling system only when the engine is stopped and cool.

WARNING

Personal injury can result from hot coolant, steam and alkali.

At operating temperature, engine coolant is hot and under pressure. The radiator and all lines to heaters or the engine contain hot coolant or steam. Any contact can cause severe burns.

Remove cooling system pressure cap slowly to relieve pressure only when engine is stopped and cooling system pressure cap is cool enough to touch with your bare hand.

Do not attempt to tighten hose connections when the coolant is hot, the hose can come off causing burns.

Cooling System Coolant Additive contains alkali. Avoid contact with skin and eyes.

NOTICE

Care must be taken to ensure that fluids are contained during performance of inspection, maintenance, testing, adjusting, and repair of the product. Be prepared to collect the fluid with suitable containers before opening any compartment or disassembling any component containing fluids.

Refer to Special Publication, NENG2500, "Cat Dealer Service Tool Catalog" or refer to Special Publication, PECJ0003, "Cat Shop Supplies and Tools Catalog" for tools and supplies suitable to collect and contain fluids on Cat products.

Dispose of all fluids according to local regulations and mandates.

1. Loosen the cooling system filler cap slowly in order to relieve pressure. Remove the cooling system filler cap.
2. If necessary, drain enough coolant from the cooling system in order to add the Cat ELC Extender.
3. Add Cat ELC Extender according to the requirements for the cooling system capacity. Refer to this Operation and Maintenance Manual, "Refill Capacities" or to this Operation and Maintenance Manual, "Fluid Recommendations" for more information.
4. Clean the cooling system filler cap. Inspect the gaskets on the cooling system filler cap. Replace the cooling system filler cap if the gaskets are damaged. Install the cooling system filler cap.

i03842450

Coolant Level - Check

SMCS Code: 1395-082

Check the coolant level when the engine is stopped and cool.

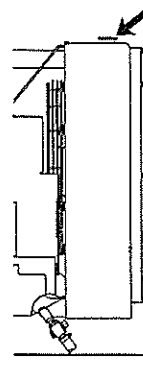


Illustration 23
Cooling system filler cap

g00285520

WARNING

Pressurized System: Hot coolant can cause serious burns. To open the cooling system filler cap, stop the engine and wait until the cooling system components are cool. Loosen the cooling system pressure cap slowly in order to relieve the pressure.

1. Remove the cooling system filler cap slowly in order to relieve pressure.
2. Maintain the coolant level within 13 mm (0.5 inch) of the bottom of the filler pipe. If the engine is equipped with a sight glass, maintain the coolant level to the proper level in the sight glass.

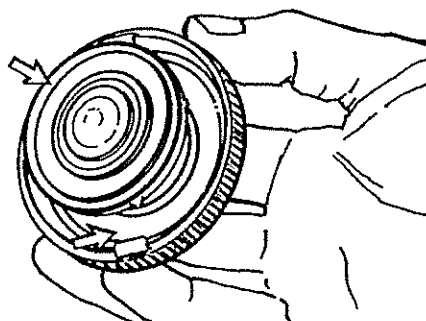


Illustration 24
Typical filler cap gaskets

g00103639

3. Clean the cooling system filler cap and check the condition of the filler cap gaskets. Replace the cooling system filler cap if the filler cap gaskets are damaged. Reinstall the cooling system filler cap.
4. Inspect the cooling system for leaks.

i05186396

Coolant Sample (Level 1) - Obtain

SMCS Code: 1350-008; 1395-008; 1395-554; 7542

Note: Obtaining a Coolant Sample (Level 1) is optional if the cooling system is filled with Cat ELC (Extended Life Coolant). Cooling systems that are filled with Cat ELC should have a Coolant Sample (Level 2) that is obtained at the recommended interval that is stated in the Maintenance Interval Schedule.

Note: Obtain a Coolant Sample (Level 1) if the cooling system is filled with any other coolant instead of Cat ELC. A Coolant Sample (Level 1) includes the following types of coolants:

- Commercial long life coolants that meet the Caterpillar Engine Coolant Specification -1 (Caterpillar EC-1)
- Cat DEAC (Diesel Engine Antifreeze/Coolant)
- Commercial heavy-duty coolant/antifreeze

Table 9

Recommended Interval		
Type of Coolant	Level 1	Level 2
Cat DEAC	Every 250 Hours ⁽¹⁾	Yearly ⁽¹⁾⁽²⁾
Cat ELC	Optional ⁽²⁾	Yearly ⁽²⁾

⁽¹⁾ This is the recommended interval for coolant samples for all conventional heavy-duty coolant/antifreeze. This is also the recommended interval for coolant samples of commercial coolants that meet the Cat EC-1 specification for engine coolant.

⁽²⁾ The Level 2 Coolant Analysis should be performed sooner if a problem is suspected or identified.

NOTICE

Always use a designated pump for oil sampling, and use a separate designated pump for coolant sampling. Using the same pump for both types of samples may contaminate the samples that are being drawn. This contaminate may cause a false analysis and an incorrect interpretation that could lead to concerns by both dealers and customers.

Note: Level 1 results may indicate a need for Level 2 Analysis.

Obtain the sample of the coolant as close as possible to the recommended sampling interval. In order to receive the full effect of S·O·S analysis, a consistent trend of data must be established. In order to establish a pertinent history of data, perform consistent samplings that are evenly spaced. Supplies for collecting samples can be obtained from your Caterpillar dealer.

Use the following guidelines for proper sampling of the coolant:

- Complete the information on the label for the sampling bottle before you begin to take the samples.
- Keep the unused sampling bottles stored in plastic bags.
- Obtain coolant samples directly from the coolant sample port. You should not obtain the samples from any other location.
- Keep the lids on empty sampling bottles until you are ready to collect the sample.
- Place the sample in the mailing tube immediately after obtaining the sample in order to avoid contamination.
- Never collect samples from expansion bottles.
- Never collect samples from the drain for a system.

Submit the sample for Level 1 analysis.

For additional information about coolant analysis, see this Operation and Maintenance Manual, "Refill Capacities and Recommendations" or consult your Caterpillar dealer.

i03907892

Coolant Sample (Level 2) - Obtain

SMCS Code: 1350-008; 1395-008; 1395-554; 7542

NOTICE

Always use a designated pump for oil sampling, and use a separate designated pump for coolant sampling. Using the same pump for both types of samples may contaminate the samples that are being drawn. This contaminate may cause a false analysis and an incorrect interpretation that could lead to concerns by both dealers and customers.

NOTICE

Care must be taken to ensure that fluids are contained during performance of inspection, maintenance, testing, adjusting and repair of the product. Be prepared to collect the fluid with suitable containers before opening any compartment or disassembling any component containing fluids.

Refer to Special Publication, NENG2500, "Caterpillar Dealer Service Tool Catalog" or refer to Special Publication, PECJ0003, "Caterpillar Shop Supplies and Tools Catalog" for tools and supplies suitable to collect and contain fluids on Caterpillar products.

Dispose of all fluids according to local regulations and mandates.

Refer to Operation and Maintenance Manual, "Cooling System Coolant Sample (Level 1) - Obtain" for the guidelines for a proper sampling of the coolant.

Submit the sample for Level 2 analysis.

For additional information about coolant analysis, see Special Publication, SEBU6251, "Caterpillar Commercial Diesel Engines Fluids Recommendations" or consult your Caterpillar dealer.

i04139169

Coolant Temperature Regulator - Replace

SMCS Code: 1355-510

Replace the water temperature regulator before the water temperature regulator fails. Replacing the water temperature regulator is a recommended preventive maintenance practice. Replacing the water temperature regulator reduces the chances for unscheduled downtime. Refer to this Operation and Maintenance Manual, "Maintenance Interval Schedule" for the proper maintenance interval.

A water temperature regulator that fails in a partially opened position can cause overheating or overcooling of the engine.

A water temperature regulator that fails in the closed position can cause excessive overheating. Excessive overheating could result in cracking of the cylinder head or piston seizure problems.

A water temperature regulator that fails in the open position will cause the engine operating temperature to be too low during partial load operation. Low engine operating temperatures during partial loads could cause an excessive carbon buildup inside the cylinders. This excessive carbon buildup could result in an accelerated wear of the piston rings and wear of the cylinder liner.

NOTICE

Failure to replace your water temperature regulator on a regularly scheduled basis could cause severe engine damage.

Caterpillar engines incorporate a shunt design cooling system and require operating the engine with a water temperature regulator installed.

If the water temperature regulator is installed incorrectly, the engine may overheat, causing cylinder head damage. Ensure that the new water temperature regulator is installed in the original position. Ensure that the water temperature regulator vent hole is open.

Do not use liquid gasket material on the gasket or cylinder head surface.

Refer to two articles in the Disassembly and Assembly Manual, "Water Temperature Regulators - Remove and Water Temperature Regulators - Install" for the replacement procedure of the water temperature regulator, or consult your Caterpillar dealer.

Note: If the water temperature regulators are replaced, drain the coolant from the cooling system to a level that is below the water temperature regulator housing.

i05186529

Cooling System Supplemental Coolant Additive (SCA) - Test/Add

SMCS Code: 1352-045; 1395-081

 WARNING

Cooling system coolant additive contains alkali. To help prevent personal injury, avoid contact with the skin and eyes. Do not drink cooling system coolant additive.

NOTICE

Excessive supplemental coolant additive concentration can form deposits on the higher temperature surfaces of the cooling system, reducing the engine's heat transfer characteristics. Reduced heat transfer could cause cracking of the cylinder head and other high temperature components.

Excessive supplemental coolant additive concentration could also result in blockage of the heat exchanger, overheating, and/or accelerated wear of the water pump seal.

Do not exceed the recommended amount of supplemental coolant additive concentration.

NOTICE

Care must be taken to ensure that fluids are contained during performance of inspection, maintenance, testing, adjusting and repair of the product. Be prepared to collect the fluid with suitable containers before opening any compartment or disassembling any component containing fluids.

Refer to Special Publication, NENG2500, "Caterpillar Dealer Service Tool Catalog" and to Special Publication, GECJ0003, "Cat Shop Supplies and Tools" for tools and supplies suitable to collect and contain fluids on Caterpillar products.

Dispose of all fluids according to applicable regulations and mandates.

Note: Caterpillar recommends an S·O·S coolant analysis (Level 1).

Cooling Systems that Use Conventional Coolant

This maintenance procedure is required for conventional coolants such as DEAC. **This maintenance is NOT required for cooling systems that are filled with Extended Life Coolant.**

Test the Concentration of the SCA

NOTICE

Do not exceed the recommended six percent supplemental coolant additive concentration.

Test the concentration of the SCA with the 8T-5296 Coolant Conditioner Test Kit.

Add the SCA, If Necessary

WARNING

Pressurized System: Hot coolant can cause serious burns. To open the cooling system filler cap, stop the engine and wait until the cooling system components are cool. Loosen the cooling system pressure cap slowly in order to relieve the pressure.

1. Remove the cooling system filler cap slowly.
2. If necessary, drain some coolant in order to allow space for the addition of the SCA.
3. Add the proper amount of SCA. For the proper amount of SCA, refer to this Operation and Maintenance Manual, "Refill Capacities" topic. The proper concentration of SCA depends on the type of coolant that is used. For the proper concentration of SCA, refer to Special Publication, SEBU6251, "Caterpillar Commercial Diesel Engine Fluids Recommendations".
4. Clean the cooling system filler cap. Install the cooling system filler cap.

Cooling Systems that Use Water and SCA

Test the Concentration of the SCA

Test the concentration of the SCA with a 298-5311 Coolant Nitrite Test Kit for SCA or perform an S·O·S Coolant Analysis. The test kit includes the following items: a tool for the testing, 30 ampoules for testing nitrite, instructions, and a case. 294-7420 Test Kit contains the refill ampoules for the 298-5311 Coolant Nitrite Test Kit. Use the instructions that are included with the test kit in order to properly conduct the testing.

Refer to this Operation and Maintenance Manual, "Maintenance Interval Schedule" for the times at which the procedures should be conducted. Test the concentration of the SCA more frequently if more frequent testing is indicated by the results of the S·O·S Coolant Analysis.

NOTICE

Do not exceed the recommended eight percent supplemental coolant additive concentration.

Add the SCA, If Necessary

WARNING

Pressurized System: Hot coolant can cause serious burns. To open the cooling system filler cap, stop the engine and wait until the cooling system components are cool. Loosen the cooling system pressure cap slowly in order to relieve the pressure.

1. Remove the cooling system filler cap slowly.
2. If necessary, drain some coolant in order to allow space for the addition of the SCA.
3. Add the proper amount of SCA. For the proper amount of SCA, refer to this Operation and Maintenance Manual, "Refill Capacities" topic. For the proper concentration of SCA, refer to Special Publication, SEBU6251, "Caterpillar Commercial Diesel Engine Fluids Recommendations".
4. Clean the cooling system filler cap. Install the cooling system filler cap.

i02933380

Crankshaft Vibration Damper - Inspect

SMCS Code: 1205-040

Damage to the crankshaft vibration damper or failure of the crankshaft vibration damper can increase torsional vibrations. This can result in damage to the crankshaft and to other engine components. A damper that is damaged can cause excessive gear train noise at variable points in the speed range.

The damper is mounted to the crankshaft which is located behind the belt guard on the front of the engine.

Visconic Damper

The visconic damper has a weight that is located inside a fluid filled case. The weight moves in the case in order to limit torsional vibration.

Inspect the damper for evidence of fluid leaks. If a fluid leak is found, determine the type of fluid. The fluid in the damper is silicone. Silicone has the following characteristics: transparent, viscous, smooth, and adhering.

If the fluid leak is oil, inspect the crankshaft seals for leaks. If a leak is observed, replace the crankshaft seals.

Inspect the damper and repair or replace the damper for any of the following reasons:

- The damper is dented, cracked, or leaking.
- The paint on the damper is discolored from heat.
- The engine has had a failure because of a broken crankshaft.
- Analysis of the oil has revealed that the front main bearing is badly worn.
- There is a large amount of gear train wear that is not caused by a lack of oil.

Refer to the Disassembly and Assembly Manual, "Vibration Damper and Pulley - Remove and Install" or consult your Caterpillar dealer for information about damper replacement.

i00174798

Driven Equipment - Check

SMCS Code: 3279-535

Refer to the OEM specifications for more information on the following maintenance recommendations for the driven equipment:

- Inspection
- Adjustment
- Lubrication
- Other maintenance recommendations

Perform any maintenance for the driven equipment which is recommended by the OEM.

i01646701

Engine - Clean

SMCS Code: 1000-070

WARNING

Personal injury or death can result from high voltage.

Moisture can create paths of electrical conductivity.

Make sure that the electrical system is OFF. Lock out the starting controls and tag the controls "DO NOT OPERATE".

NOTICE

Accumulated grease and oil on an engine is a fire hazard. Keep the engine clean. Remove debris and fluid spills whenever a significant quantity accumulates on the engine.

Periodic cleaning of the engine is recommended. Steam cleaning the engine will remove accumulated oil and grease. A clean engine provides the following benefits:

- Easy detection of fluid leaks
- Maximum heat transfer characteristics
- Ease of maintenance

Note: Caution must be used in order to prevent electrical components from being damaged by excessive water when you clean the engine. Avoid electrical components such as the alternator, the starter, and the ECM.

i03993690

Engine Air Cleaner Element (Dual Element) - Inspect/Clean/Replace (If Equipped)

SMCS Code: 1051; 1054-040; 1054-070; 1054-510

NOTICE

Never run the engine without an air cleaner element installed. Never run the engine with a damaged air cleaner element. Do not use air cleaner elements with damaged pleats, gaskets or seals. Dirt entering the engine causes premature wear and damage to engine components. Air cleaner elements help to prevent air-borne debris from entering the air inlet.

NOTICE

Never service the air cleaner element with the engine running since this will allow dirt to enter the engine.

Servicing the Air Cleaner Elements

If the air cleaner element becomes plugged, the air can split the material of the air cleaner element. Unfiltered air will drastically accelerate internal engine wear. Your Caterpillar dealer has the proper air cleaner elements for your application. Consult your Caterpillar dealer for the correct air cleaner element.

- Check the precleaner (if equipped) daily for accumulation of dirt and debris. Remove any dirt and debris, as needed.
- Operating conditions (dust, dirt, and debris) may require more frequent service of the air cleaner element.
- The air cleaner element may be cleaned up to six times if the element has been properly cleaned and inspected.
- The air cleaner element should be replaced at least one time per year. This replacement should be performed regardless of the number of cleanings.

Replace the dirty paper air cleaner elements with clean air cleaner elements. Before installation, check the air cleaner elements thoroughly for tears and/or holes in the filter material. Inspect the gasket or the seal of the air cleaner element for damage. Maintain a supply of suitable air cleaner elements for replacement purposes.

Dual Element Air Cleaners

The dual element air cleaner contains a primary air cleaner element and a secondary air cleaner element. The primary air cleaner element can be used up to six times if the element has been properly cleaned and inspected. The primary air cleaner element should be replaced at least one time per year. This replacement should be performed regardless of the number of cleanings.

The secondary air cleaner element is not serviceable or washable. The secondary air cleaner element should be removed and discarded for every three cleanings of the primary air cleaner element. When the engine is operating in environments that are dusty or dirty, air cleaner elements may require more frequent replacement.

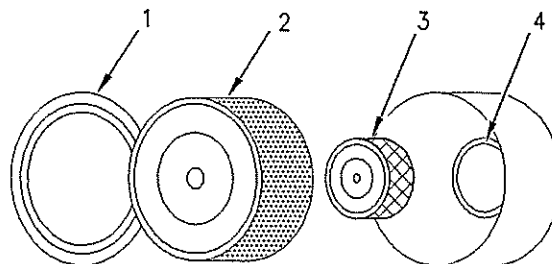


Illustration 25

g00736431

- (1) Cover
- (2) Primary air cleaner element
- (3) Secondary air cleaner element
- (4) Air inlet for the turbocharger

1. Remove the cover. Remove the primary air cleaner element.
2. The secondary air cleaner element should be removed and discarded for every three cleanings of the primary air cleaner element.

Note: Refer to "Cleaning the Primary Air Cleaner Elements".

3. Cover the air inlet to the turbocharger with tape in order to keep out dirt.
4. Clean the inside of the air cleaner cover and body with a clean, dry cloth.
5. Remove the tape from the air inlet of the turbocharger. Install the secondary air cleaner element. Install a primary air cleaner element that is new or cleaned.
6. Install the air cleaner cover.
7. Reset the air cleaner service indicator.

Cleaning the Primary Air Cleaner Elements

NOTICE

Caterpillar recommends certified air filter cleaning services that are available at Caterpillar dealers. The Caterpillar cleaning process uses proven procedures to assure consistent quality and sufficient filter life.

Observe the following guidelines if you attempt to clean the filter element:

Do not tap or strike the filter element in order to remove dust.

Do not wash the filter element.

Use low pressure compressed air in order to remove the dust from the filter element. Air pressure must not exceed 207 kPa (30 psi). Direct the air flow up the pleats and down the pleats from the inside of the filter element. Take extreme care in order to avoid damage to the pleats.

Do not use air filters with damaged pleats, gaskets, or seals. Dirt entering the engine will cause damage to engine components.

The primary air cleaner element can be used up to six times if the element has been properly cleaned and inspected. When the primary air cleaner element is cleaned, check for rips or tears in the filter material. The primary air cleaner element should be replaced at least one time per year. This replacement should be performed regardless of the number of cleanings.

Use clean primary air cleaner elements while dirty elements are being cleaned.

NOTICE

Do not clean the air cleaner elements by bumping or tapping. This could damage the seals. Do not use elements with damaged pleats, gaskets or seals. Damaged elements will allow dirt to pass through. Engine damage could result.

Visually inspect the primary air cleaner elements before cleaning. Inspect the air cleaner elements for damage to the seal, the gaskets, and the outer cover. Discard any damaged air cleaner elements.

There are two common methods that are used to clean primary air cleaner elements:

- Pressurized air
- Vacuum cleaning

Pressurized Air

Pressurized air can be used to clean primary air cleaner elements that have not been cleaned more than two times. Pressurized air will not remove deposits of carbon and oil. Use filtered, dry air with a maximum pressure of 207 kPa (30 psi).

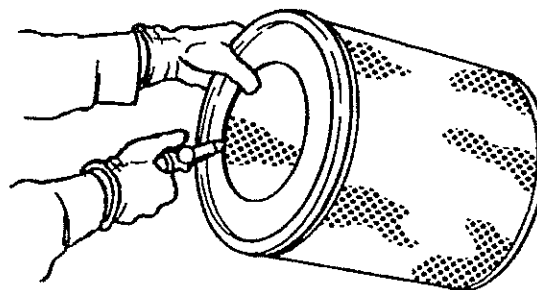


Illustration 26

g00281692

Note: When the primary air cleaner elements are cleaned, always begin with the clean side (inside) in order to force dirt particles toward the dirty side (outside).

Aim the hose so that the air flows inside the element along the length of the filter to prevent damage to the paper pleats. Do not aim the stream of air directly at the primary air cleaner element. Dirt could be forced further into the pleats.

Note: Refer to "Inspecting the Primary Air Cleaner Elements".

Vacuum Cleaning

Vacuum cleaning is a good method for cleaning primary air cleaner elements which require daily cleaning because of a dry, dusty environment. Cleaning with pressurized air is recommended prior to vacuum cleaning. Vacuum cleaning will not remove deposits of carbon and oil.

Note: Refer to "Inspecting the Primary Air Cleaner Elements".

Inspecting the Primary Air Cleaner Elements

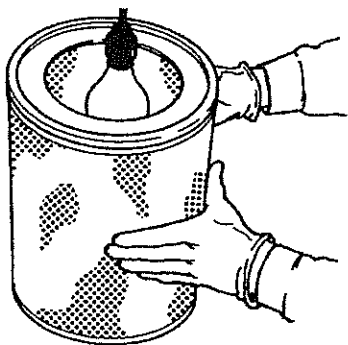


Illustration 27

g00281693

Inspect the clean, dry primary air cleaner element. Use a 60w blue light in a dark room or in a similar facility. Place the blue light in the primary air cleaner element. Rotate the primary air cleaner element. Inspect the primary air cleaner element for tears and/or holes. Inspect the primary air cleaner element for light that may show through the filter material. To confirm the result, compare the primary air cleaner element to a new air cleaner element that has the same part number.

Do not use a primary air cleaner element that has any tears and/or holes in the filter material. Do not use a primary air cleaner element with damaged pleats, gaskets, or seals. Discard damaged primary air cleaner elements.

Storing Primary Air Cleaner Elements

If a primary air cleaner element that passes inspection will not be used, the primary air cleaner element can be stored for future use.

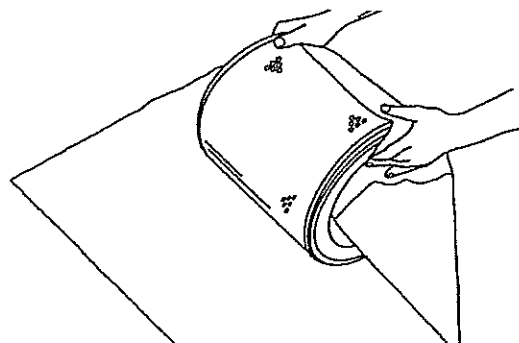


Illustration 28

g00281694

Do not use paint, a waterproof cover, or plastic as a protective covering for storage. An air flow restriction may result. To protect against dirt and damage, wrap the primary air cleaner elements in Volatile Corrosion Inhibited (VCI) paper.

Place the primary air cleaner element into a box for storage. For identification, mark the outside of the box and mark the primary air cleaner element. Include the following information:

- Date of cleaning
- Number of cleanings

Store the box in a dry location.

i01900118

Engine Air Cleaner Service Indicator - Inspect (If Equipped)

SMCS Code: 7452-040

Some engines may be equipped with a different service indicator.

Some engines are equipped with a differential gauge for inlet air pressure. The differential gauge for inlet air pressure displays the difference in the pressure that is measured before the air cleaner element and the pressure that is measured after the air cleaner element. As the air cleaner element becomes dirty, the pressure differential rises. If your engine is equipped with a different type of service indicator, follow the OEM recommendations in order to service the air cleaner service indicator.

The service indicator may be mounted on the air cleaner housing or in a remote location.

i02927289

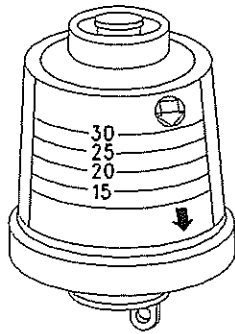


Illustration 29

g00103777

Typical service indicator

Observe the service indicator. The air cleaner element should be cleaned or the air cleaner element should be replaced when one of the following conditions occur:

- The yellow diaphragm enters the red zone.
- The red piston locks in the visible position.

Test the Service Indicator

Service indicators are important instruments.

- Check for ease of resetting. The service indicator should reset in less than three pushes.
- Check the movement of the yellow core when the engine is accelerated to the engine rated speed. The yellow core should latch approximately at the greatest vacuum that is attained.

If the service indicator does not reset easily, or if the yellow core does not latch at the greatest vacuum, the service indicator should be replaced. If the new service indicator will not reset, the hole for the service indicator may be plugged.

The service indicator may need to be replaced frequently in environments that are severely dusty, if necessary. Replace the service indicator annually regardless of the operating conditions. Replace the service indicator when the engine is overhauled, and whenever major engine components are replaced.

Note: When a new service indicator is installed, excessive force may crack the top of the service indicator. Tighten the service indicator to a torque of 2 N·m (18 lb in).

Engine Air Precleaner - Check/Clean

SMCS Code: 1055-070; 1055-535

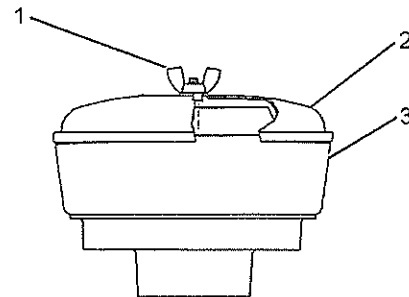


Illustration 30

g01453058

Typical engine air pre-cleaner

- (1) Wing nut
(2) Cover
(3) Body

Remove wing nut (1) and cover (2). Check for an accumulation of dirt and debris in body (3). Clean the body, if necessary.

After cleaning the pre-cleaner, install cover (2) and wing nut (1).

Note: When the engine is operated in dusty applications, more frequent cleaning is required.

i02327200

Engine Crankcase Breather - Clean

SMCS Code: 1317-070

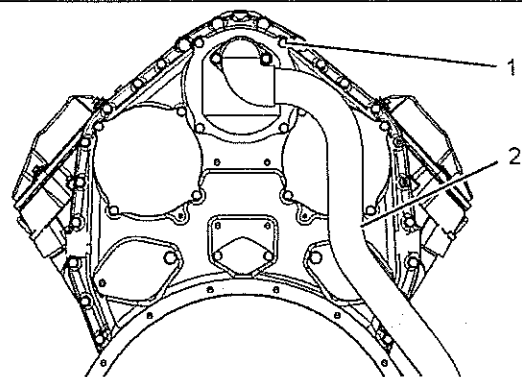


Illustration 31

g01162493

The crankcase breather is located on the back of the engine.

1. Remove the tube (2) from the outlet of the breather and loosen the clamp.
2. Remove the bolts (1) and remove the breather from the engine.
3. Check the condition of the seal. Replace the seal if the seal is damaged.
4. Remove the breather element. Wash the breather element and wash the breather in a clean nonflammable solvent.
5. Shake the breather element until the breather element is dry. You may also use pressurized air in order to dry the breather element.
6. Check the condition of the tube. Replace the tube if the tube is damaged.
7. Install the element into the breather and install the breather.
8. Install the tube onto the outlet of the breather cover and tighten the clamp.

i02139969

Engine Mounts - Inspect

SMCS Code: 1152-040; 1152

Inspect the engine mounts for deterioration and for proper bolt torque. Engine vibration can be caused by the following conditions:

- Improper mounting of the engine
- Deterioration of the engine mounts

Any engine mount that shows deterioration should be replaced. Refer to the Specifications Manual, SENR3130, "Torque Specifications". Refer to your Caterpillar dealer for more information.

i05187192

Engine Oil Level - Check

SMCS Code: 1348-535-FLV

WARNING

Hot oil and hot components can cause personal injury. Do not allow hot oil or hot components to contact the skin.

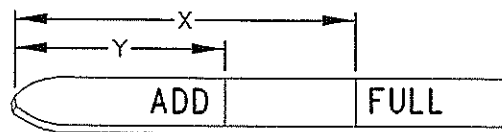


Illustration 32

g00110310

(Y) "ADD" mark
(X) "FULL" mark

NOTICE

Perform this maintenance with the engine stopped.

NOTICE

Care must be taken to ensure that fluids are contained during performance of inspection, maintenance, testing, adjusting, and repair of the product. Be prepared to collect the fluid with suitable containers before opening any compartment or disassembling any component containing fluids.

Refer to Special Publication, NENG2500, "Cat Dealer Service Tool Catalog" or refer to Special Publication, PECJ0003, "Cat Shop Supplies and Tools Catalog" for tools and supplies suitable to collect and contain fluids on Cat products.

Dispose of all fluids according to local regulations and mandates.

1. Maintain the oil level between "ADD" mark (Y) and "FULL" mark (X) on the oil level gauge. Do not fill the crankcase above "FULL" mark (X).

NOTICE

Engine damage can occur if the crankcase is filled above the "FULL" mark on the oil level gauge (dipstick).

An overfull crankcase can cause the crankshaft to dip into the oil. This will reduce the power that is developed and also force air bubbles into the oil. These bubbles (foam) can cause the following problems: reduction of the oil's ability to lubricate, reduction of oil pressure, inadequate cooling, oil blowing out of the crankcase breathers, and excessive oil consumption.

Excessive oil consumption will cause deposits to form on the pistons and in the combustion chamber. Deposits in the combustion chamber lead to the following problems: guttering of the valves, packing of carbon under the piston rings, and wear of the cylinder liner.

If the oil level is above the "FULL" mark on the oil level gauge, drain some of the oil immediately.

2. Remove the oil filler cap and add oil, if necessary. For information about choosing the correct oil for the engine, refer to one of the following articles: Operation and Maintenance Manual, "Refill Capacities and Recommendations" or Operation and Maintenance Manual, "Fluid Recommendations". Do not fill the crankcase above "FULL" mark (X) on the oil level gauge. Clean the oil filler cap. Install the oil filler cap.
3. Record the amount of oil that is added. For the next oil sample and analysis, include the total amount of oil that has been added since the previous sample. This information will help to provide the most accurate oil analysis.

i04237495

Engine Oil Sample - Obtain

SMCS Code: 1348-554-SM

In addition to a good preventive maintenance program, Caterpillar recommends using S-O-S oil analysis at regularly scheduled intervals. S-O-S oil analysis provides infrared analysis, which is required for determining nitration and oxidation levels.

Obtain the Sample and the Analysis

WARNING

Hot oil and hot components can cause personal injury. Do not allow hot oil or hot components to contact the skin.

Before you take the oil sample, complete the Label, PEEP5031 for identification of the sample. In order to help obtain the most accurate analysis, provide the following information:

- Engine model
- Service hours on the engine
- The number of hours that have accumulated since the last oil change
- The amount of oil that has been added since the last oil change

To ensure that the sample is representative of the oil in the crankcase, obtain a warm, mixed oil sample.

To avoid contamination of the oil samples, the tools and the supplies that are used for obtaining oil samples must be clean.

Caterpillar recommends using the sampling valve in order to obtain oil samples. The quality and the consistency of the samples are better when the sampling valve is used. The location of the sampling valve allows oil that is flowing under pressure to be obtained during normal engine operation.

The 169-8373 Fluid Sampling Bottle is recommended for use with the sampling valve. The fluid sampling bottle includes the parts that are needed for obtaining oil samples. Instructions are also provided.

NOTICE

Always use a designated pump for oil sampling, and use a separate designated pump for coolant sampling. Using the same pump for both types of samples may contaminate the samples that are being drawn. This contaminate may cause a false analysis and an incorrect interpretation that could lead to concerns by both dealers and customers.

If the engine is not equipped with a sampling valve, use the 1U-5718 Vacuum Pump. The pump is designed to accept sampling bottles. Disposable tubing must be attached to the pump for insertion into the sump.

For instructions, see Special Publication, PEGJ0047, "How To Take A Good S-O-S Oil Sample". Consult your Cat dealer for complete information and assistance in establishing an S-O-S program for your engine.

i05187194

Engine Oil and Filter - Change

SMCS Code: 1318-510

WARNING

Hot oil and hot components can cause personal injury. Do not allow hot oil or hot components to contact the skin.

Do not drain the oil when the engine is cold. As the oil cools, suspended waste particles settle on the bottom of the oil pan. The waste particles are not removed with the draining cold oil. Drain the crankcase with the engine stopped. Drain the crankcase with the oil warm. This draining method allows the waste particles that are suspended in the oil to be drained properly.

Failure to follow this recommended procedure will cause the waste particles to be recirculated through the engine lubrication system with the new oil.

Drain the Engine Oil

After the engine has been run at the normal operating temperature, stop the engine. Use one of the following methods to drain the engine crankcase oil:

- If the engine is equipped with a drain valve, turn the drain valve knob counterclockwise in order to drain the oil. After the oil has drained, turn the drain valve knob clockwise in order to close the drain valve.
- If the engine is not equipped with a drain valve, remove the oil drain plug in order to allow the oil to drain. If the engine is equipped with a shallow sump, remove the bottom oil drain plugs from both ends of the oil pan.

After the oil has drained, the oil drain plugs should be cleaned and installed.

Replace the Oil Filter

NOTICE

Caterpillar oil filters are built to Caterpillar specifications. Use of an oil filter not recommended by Caterpillar could result in severe engine damage to the engine bearings, crankshaft, etc., as a result of the larger waste particles from unfiltered oil entering the engine lubricating system. Only use oil filters recommended by Caterpillar.

1. Remove the oil filter with a 1U-8760 Chain Wrench.
2. Cut the oil filter open with a 175-7546 Oil Filter Cutter Gp. Break apart the pleats and inspect the oil filter for metal debris. An excessive amount of metal debris in the oil filter may indicate early wear or a pending failure.

Use a magnet to differentiate between the ferrous metals and the nonferrous metals that are found in the oil filter element. Ferrous metals may indicate wear on the steel and cast iron parts of the engine.

Nonferrous metals may indicate wear on the aluminum parts, brass parts, or bronze parts of the engine. Parts that may be affected include the following items: main bearings, rod bearings, turbocharger bearings, and cylinder heads.

Due to normal wear and friction, it is not uncommon to find small amounts of debris in the oil filter. Consult your Caterpillar dealer in order to arrange for a further analysis if an excessive amount of debris is found in the oil filter.

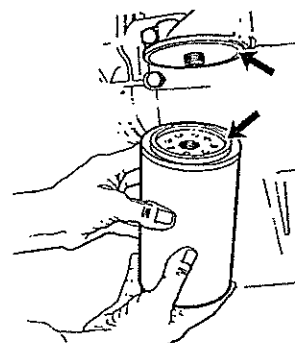


Illustration 33

g00103713

Typical filter mounting base and filter gasket

3. Clean the sealing surface of the filter mounting base. Ensure that all of the old oil filter gasket is removed.
4. Apply clean engine oil to the new oil filter gasket.

NOTICE

Do not fill the oil filters with oil before installing them. This oil would not be filtered and could be contaminated. Contaminated oil can cause accelerated wear to engine components.

5. Install the oil filter. Tighten the oil filter until the oil filter gasket contacts the base. Tighten the oil filter by hand according to the instructions that are shown on the oil filter. Do not overtighten the oil filter.

Fill the Engine Crankcase

1. Remove the oil filler cap. Refer to the Operation and Maintenance Manual, "Refill Capacities and Recommendations" or Operation and Maintenance Manual, "Refill Capacities" for more information.

NOTICE

If equipped with an auxiliary oil filter system or a remote oil filter system, follow the OEM or filter manufacturer's recommendations. Under filling or overfilling the crankcase with oil can cause engine damage.

NOTICE

To prevent crankshaft bearing damage, crank the engine with the fuel OFF. This will fill the oil filters before starting the engine. Do not crank the engine for more than 30 seconds.

i04000664

2. Start the engine and run the engine at "LOW IDLE" for 2 minutes. Perform this procedure in order to ensure that the lubrication system has oil and that the oil filters are filled. Inspect the oil filter for oil leaks.
3. Stop the engine and allow the oil to drain back to the sump for a minimum of 10 minutes.
4. Remove the oil level gauge in order to check the oil level. Maintain the oil level between the "ADD" and "FULL" marks on the oil level gauge.

i00626013

Engine Protective Devices - Check

SMCS Code: 7400-535

Alarms and shutoffs must function properly. Alarms provide timely warning to the operator. Shutoffs help to prevent damage to the engine. It is impossible to determine if the engine protective devices are in good working order during normal operation. Malfunctions must be simulated in order to test the engine protective devices.

A calibration check of the engine protective devices will ensure that the alarms and shutoffs activate at the setpoints. Ensure that the engine protective devices are functioning properly.

NOTICE

During testing, abnormal operating conditions must be simulated.

The tests must be performed correctly in order to prevent possible damage to the engine.

To prevent damage to the engine, only authorized service personnel or your Caterpillar dealer should perform the tests.

Visual Inspection

Visually check the condition of all gauges, sensors and wiring. Look for wiring and components that are loose, broken, or damaged. Damaged wiring or components should be repaired or replaced immediately.

Engine Speed/Timing Sensor - Clean/Inspect

SMCS Code: 1905-040; 1905-070; 1907-040; 1907-070

NOTICE

Failure to perform the inspection at less than 4500 hours will not void the emission-related warranty.

Two speed/timing sensors (1) and (2) are mounted in the front housing. Both of these sensors are pulled into position by bolts.

1. Remove the speed/timing sensors from the front housing. Check the condition of the plastic end of the speed/timing sensors for wear and/or contaminants.
 2. Clean the metal shavings and other debris from the face of the speed/timing sensors. Use the procedure in the Service Manual in order to calibrate the speed/timing sensors.
-

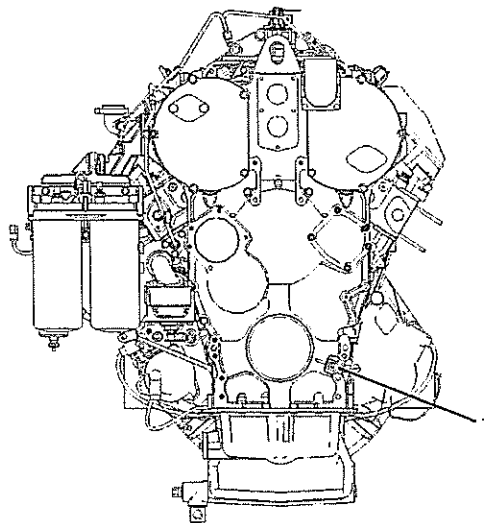


Illustration 34

g02143194

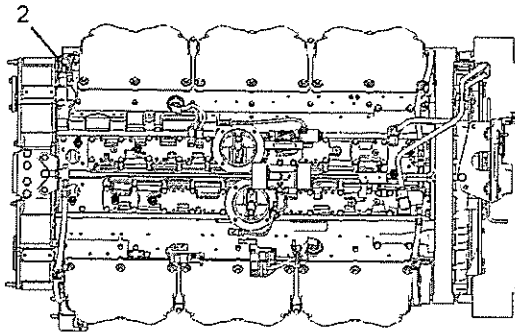


Illustration 35

g02366556

i02703023

Engine Storage Procedure - Check

SMCS Code: 1000-535

Caterpillar recommends storage procedures and start-up procedures for all engines that are stored for more than 1 month. These procedures provide maximum protection to internal engine components. Refer to Special Instruction, SEHS9031, "Storage Procedure For Caterpillar Products" for information on these procedures.

An extension of the oil change interval to 12 months is permitted if you follow the required procedures for storage and start-up. This extension is permitted if the following intervals in the Operation and Maintenance Manual, "Maintenance Interval Schedule" have not been reached:

- Operating hours
- Fuel consumption

i03964791

Engine Valve Lash - Check

SMCS Code: 1105-535

Note: Procedures for adjusting the valve lash can be found in Systems Operation/Testing and Adjusting, "Valve Lash Adjustment". Consult your Cat dealer for assistance.

WARNING

Ensure that the engine cannot be started while this maintenance is being performed. To help prevent possible injury, do not use the starting motor to turn the flywheel.

Hot engine components can cause burns. Allow additional time for the engine to cool before measuring/adjusting valve lash clearance.

i01597115

Engine Valve Rotators - Inspect

SMCS Code: 1109-040

WARNING

When inspecting the valve rotators, protective glasses or face shield and protective clothing must be worn, to help prevent being burned by hot oil or spray.

Engine valve rotators rotate the valves when the engine runs. This helps to prevent deposits from building up on the valves and the valve seats.

Perform the following steps after the engine valve lash is set, but before the valve covers are installed:

1. Start the engine according to Operation and Maintenance Manual, "Engine Starting" (Operation Section) for the procedure.
2. Operate the engine at low idle.
3. Observe the top surface of each valve rotator. The valve rotators should turn slightly when the valves close.

NOTICE

A valve rotator which does not operate properly will accelerate valve face wear and valve seat wear and shorten valve life. If a damaged rotator is not replaced, valve face guttering could result and cause pieces of the valve to fall into the cylinder. This can cause piston and cylinder head damage.

If a valve fails to rotate, consult your Caterpillar dealer.

i02784507

i03623731

Fan Drive Bearing - Lubricate

SMCS Code: 1359-086-BD

Some of the fan drives have grease fittings and some of the fan drives do not have grease fittings. If there is no grease fitting, periodic lubrication is not required. The fan drive requires grease only if the fan drive is equipped with a zerk.

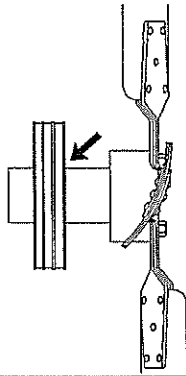


Illustration 36

g00746166

Typical location of the grease fitting (if equipped) that is for the fan drive bearing

The pulley is shown with the belt guards that have been removed.

Lubricate the grease fitting that is on the fan drive bearing with High Speed Ball Bearing Grease or the equivalent.

Inspect the fan drive pulley assembly for wear or for damage. If the shaft is loose, an inspection of the internal components should be performed. Refer to the Systems Operation Testing and Adjusting Manual for additional information.

i02053753

Fan Drive Bearing - Replace

SMCS Code: 1359-510-BD

1. Remove Bearings. Refer to Disassembly and Assembly, "Bearing Removal".
2. Measure the bearing housings for roundness and for proper size.
3. Replace the bearings.

Fuel Injector - Inspect/Adjust

SMCS Code: 1290-025; 1290-040

! WARNING

Be sure the engine cannot be started while this maintenance is being performed. To prevent possible injury, do not use the starting motor to turn the flywheel.

Hot engine components can cause burns. Allow additional time for the engine to cool before measuring/adjusting the unit injectors.

The electronic unit injectors use high voltage. Disconnect the unit injector enable circuit connector in order to prevent personal injury. Do not come in contact with the injector terminals while the engine is running.

The operation of Caterpillar engines with improper adjustments of the electronic unit injector can reduce engine efficiency. This reduced efficiency could result in excessive fuel usage and/or shortened engine component life.

Only qualified service personnel should perform this maintenance. Refer to the following topics for your engine for the correct procedure: Refer to the Systems Operation, Testing and Adjusting, "Electronic Unit Injector - Test" for the test procedure, and Systems Operation, Testing and Adjusting, "Electronic Unit Injector - Adjust" for the correct procedure for adjusting the injectors.

NOTICE

The camshafts must be correctly timed with the crankshaft before an adjustment of the lash for the fuel injector is made. The timing pins must be removed from the camshafts before the crankshaft is turned or damage to the cylinder block will be the result.

i04328629

Fuel System - Prime

SMCS Code: 1250-548; 1258-548

! WARNING

Fuel leaked or spilled onto hot surfaces or electrical components can cause a fire. To help prevent possible injury, turn the start switch off when changing fuel filters or water separator elements. Clean up fuel spills immediately.

Priming the fuel system fills the fuel filters. Priming the fuel system also removes air from the fuel system. This procedure is used primarily when the engine runs out of fuel.

1. Hold ON until the audible tone of the pump changes.

NOTICE

Do not crank the engine continuously for more than 30 seconds. Allow the starting motor to cool for two minutes before cranking the engine again.

2. If the engine does not start, repeat Step 1 in order to start the engine.

i02049797

Fuel System Primary Filter (Water Separator) Element - Replace

SMCS Code: 1260-510-FQ; 1263-510-FQ

Water in the fuel can cause the engine to run rough. Water in the fuel may cause an electronic unit injector to fail. If the fuel has been contaminated with water, the element should be changed before the regularly scheduled interval.

The primary filter/water separator also provides filtration in order to help extend the life of the secondary fuel filter. The element should be changed regularly. Install a vacuum gauge. Change the element for the primary filter/water separator if the pressure is at 50 to 70 kPa (15 to 20 inches Hg).

Replace the Element

WARNING

Fuel leaked or spilled onto hot surfaces or electrical components can cause a fire. To help prevent possible injury, turn the start switch off when changing fuel filters or water separator elements. Clean up fuel spills immediately.

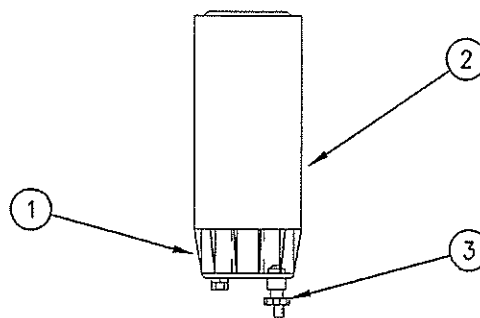


Illustration 37

g00668636

- (1) Bowl
- (2) Element
- (3) Drain

1. Stop the engine.
2. Turn the start switch to the "OFF" position.
3. Shut off the fuel tank supply valve to the engine.
4. If the primary fuel filter is equipped with a drain valve (3), open the drain valve in order to drain any fuel from the filter case. Close the drain valve (3).

NOTICE

Use a suitable container to catch any fuel that might spill. Clean up any spilled fuel immediately.

5. Remove the fuel filter bowl (1) and wash the fuel filter bowl with clean diesel fuel.
6. Remove the fuel filter (2).
7. Clean the gasket sealing surface of the fuel filter base. Ensure that all of the old gasket is removed.
8. Apply clean diesel fuel to the new fuel filter gasket.

NOTICE

In order to maximize fuel system life and prevent premature wear out from abrasive particles in the fuel, use Caterpillar fuel filters.

Consult your Caterpillar dealer for proper part numbers.

9. Install the new fuel filter (2). Spin the fuel filter onto the fuel filter base until the gasket contacts the base. Use the rotation index marks on the filters as a guide for proper tightening. Tighten the filter for an additional 3/4 turn by hand. Do not overtighten the filter.

NOTICE

Do not fill the fuel filters with fuel before installing them. The fuel would not be filtered and could be contaminated. Contaminated fuel will cause accelerated wear to fuel system parts.

10. Install the clean fuel filter bowl (1) on the new fuel filter.

NOTICE

The water separator is under suction during normal engine operation. Ensure that the vent plug is tightened securely to help prevent air from entering the fuel system.

11. Open the fuel tank supply valve.
12. Start the engine and check for leaks. Run the engine for one minute. Stop the engine and check the engine for leaks again.

Detection of leaks is very difficult especially if the engine is running. The primary filter/water separator is under suction. A leak will allow air to enter the fuel. The air in the fuel can cause low power due to aeration of the fuel. If air enters the fuel, check the components for overtightening or undertightening.

i01463757

Fuel System Primary Filter/Water Separator - Drain

SMCS Code: 1260-543; 1263-543

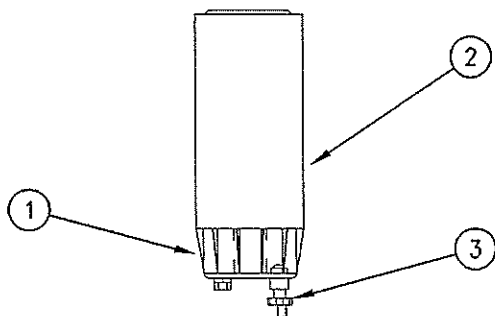


Illustration 38

g00668636

- (1) Bowl
- (2) Element
- (3) Drain

Bowl (1) should be monitored daily for signs of water. If water is present, drain the water from the bowl.

1. Open drain (3). The drain is a self-ventilated drain. Catch the draining water in a suitable container. Dispose of the water properly.
2. Close drain (3).

NOTICE

The water separator is under suction during normal engine operation. Ensure that the drain valve is tightened securely to help prevent air from entering the fuel system.

i04003481

Fuel System Secondary Filter - Replace

SMCS Code: 1261-510-SE

WARNING

Fuel leaked or spilled onto hot surfaces or electrical components can cause a fire. To help prevent possible injury, turn the start switch off when changing fuel filters or water separator elements. Clean up fuel spills immediately.

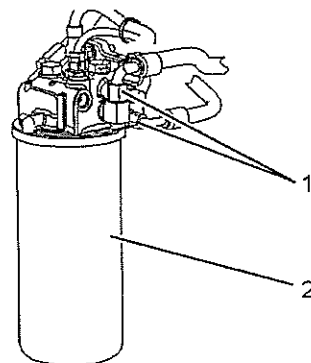


Illustration 39

g02178189

- (1) Fuel supply connections
- (2) Fuel filter

NOTICE

Do not allow dirt to enter the fuel system. Thoroughly clean the area around a fuel system component that will be disconnected. Fit a suitable cover over any disconnected fuel system components.

NOTICE

Use a suitable container to catch any fuel that might spill. Clean up any spilled fuel immediately.

1. It may be necessary to relieve residual fuel pressure from the fuel system before removing the fuel filter.

Loosen one of the fuel supply connections (1) in order to purge any residual pressure.

NOTICE

Do not loosen fuel lines or fittings at the fuel manifold or ECM. The engine components may be damaged.

2. Remove the used fuel filter.
3. Clean the gasket sealing surface of the fuel filter base. Ensure that all of the old gasket is removed.
4. Apply clean diesel fuel to the new fuel filter gasket.

NOTICE

Do not fill the secondary fuel filter with fuel before installing. The fuel would not be filtered and could be contaminated. Contaminated fuel will cause accelerated wear to fuel system parts.

5. Install the new fuel filter. Spin the fuel filter onto the fuel filter base until the gasket contacts the base. Use the rotation index marks on the filters as a guide for proper tightening. Tighten the filter for an additional 3/4 turn by hand. Do not overtighten the filter.

i05111531

Fuel Tank Water and Sediment - Drain

SMCS Code: 1273-543-M&S

NOTICE

Care must be taken to ensure that fluids are contained during performance of inspection, maintenance, testing, adjusting, and repair of the product. Be prepared to collect the fluid with suitable containers before opening any compartment or disassembling any component containing fluids.

Refer to Special Publication, NENG2500, "Cat Dealer Service Tool Catalog" or refer to Special Publication, PECJ0003, "Cat Shop Supplies and Tools Catalog" for tools and supplies suitable to collect and contain fluids on Cat products.

Dispose of all fluids according to local regulations and mandates.

Fuel Tank

Fuel quality is critical to the performance and to the service life of the engine. Water in the fuel can cause excessive wear to the fuel system. Condensation occurs during the heating and cooling of fuel. The condensation occurs as the fuel passes through the fuel system and the fuel returns to the fuel tank. This causes water to accumulate in fuel tanks. Draining the fuel tank regularly and obtaining fuel from reliable sources can help to eliminate water in the fuel.

Drain the Water and the Sediment

Fuel tanks should contain some provision for draining water and draining sediment from the bottom of the fuel tanks.

Open the drain valve on the bottom of the fuel tank in order to drain the water and the sediment. Close the drain valve.

Note: Failure to close the drain can allow air into the system, which could have detrimental results to performance.

Check the fuel daily. Drain the water and sediment from the fuel tank after operating the engine. Drain the water and sediment from the fuel tank after the fuel tank has been filled. Allow 5 to 10 minutes before performing this procedure.

Fill the fuel tank after operating the engine in order to drive out moist air. This procedure will help prevent condensation. Do not fill the tank to the top. The fuel expands as the fuel gets warm. The tank may overflow.

Some fuel tanks use supply pipes that allow water and sediment to settle below the end of the fuel supply pipe. Some fuel tanks use supply lines that take fuel directly from the bottom of the tank. If the engine is equipped with this system, regular maintenance of the fuel system filter is important.

Fuel Storage Tanks

Drain the water and the sediment from the fuel storage tank during the following conditions:

- Weekly
- Oil change
- Refill of the tank

This procedure will help prevent water or sediment from being pumped from the storage tank into the engine fuel tank. A four micron(c) absolute filter for the breather vent on the fuel tank is also recommended.

If a bulk storage tank has been refilled or moved recently, allow adequate time for the sediment to settle before filling the engine fuel tank. Internal baffles in the bulk storage tank will also help trap sediment. Filtering fuel that is pumped from the storage tank helps to ensure the quality of the fuel. When possible, water separators should be used.

i03972634

Fumes Disposal Filter Element - Replace (Open Crankcase Ventilation (OCV) Filter)

SMCS Code: 1074

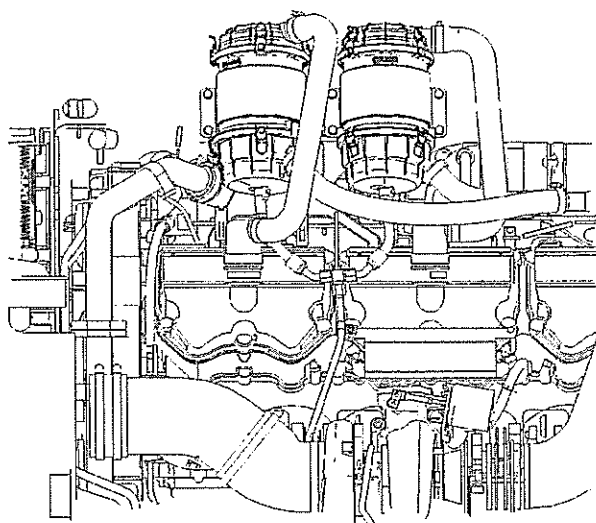


Illustration 40

g02162965

The filter for the open crankcase ventilation system may be located toward the front or toward the rear of the left side of the engine. A filter that has been used may contain a small amount of engine oil.

NOTICE

Care must be taken to ensure that fluids are contained during performance of inspection, maintenance, testing, adjusting and repair of the machine. Be prepared to collect the fluid with suitable containers before opening any compartment or disassembling any component containing fluids.

Refer to Special Publication, NENG2500, "Caterpillar Tools and Shop Products Guide", for tools and supplies suitable to collect and contain fluids in Caterpillar machines.

Dispose of all fluids according to local regulations and mandates.

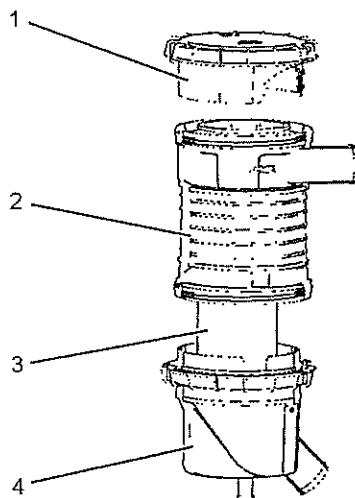


Illustration 41

g02021434

- (1) Cap
- (2) Housing for the filter element
- (3) Filter element
- (4) Cup

Remove either the cap or the cup from the housing for the OCV filter. Remove the OCV filter. The filter may not be used again. Dispose of the filter. Place a new OCV filter inside the filter housing. If the cap was removed, replace the cap. If the cup was removed, replace the cup. Tighten hand tight.

Note: Caterpillar will not be held liable for an engine that does not comply with EPA emissions standards due to modification of the OCV filter or due to the use of a filter that is not approved by Caterpillar.

i04301694

Hoses and Clamps - Inspect/Replace

SMCS Code: 7554-040; 7554-510

Hoses and clamps must be inspected periodically in order to ensure safe operation and continuous operation of the engine. Take proper safety precautions before inspecting or replacing hoses and clamps.

Note: Always use a board or cardboard when the engine components are checked for leaks. Leaking fluid that is under pressure can cause serious injury or possible death. Leaks that are the size of a pin hole are included. Refer to Operation and Maintenance Manual, "General Hazard Information" for more information.

Inspect the Hoses and the Clamps

Inspect all hoses for leaks that are caused by the following conditions. Replace any hose which exhibits any of the following conditions. Failure to replace a hose which exhibits any of the following conditions may result in a hazardous situation.

- Hoses which are cracked
- Hoses which are soft
- Outer covering that is chafed or cut
- Exposed wire that is used for reinforcement
- Outer covering that is ballooning locally
- Flexible part of the hose that is kinked or crushed
- Armoring that is embedded in the outer covering
- Hoses which exhibit signs of leakage which are not the result of loose couplings or clamps

Inspect all clamps for the following conditions. Replace any clamp which exhibits signs of any of the following conditions.

- Cracking
- Looseness
- Damage

Inspect all couplings for leaks. Replace any coupling which exhibits signs of leaks.

Each installation application can be different. The differences depend on the following factors:

- Type of hose
- Type of fitting material
- Anticipated expansion and contraction of the hose
- Anticipated expansion and contraction of the fittings

Due to extreme temperature changes, the hose will heat set. Heat setting causes hose clamps to loosen which can result in leaks. A constant torque hose clamp will help to prevent loose hose clamps.

Replace hoses that are cracked or soft. Replace hoses that show signs of leakage. Replace hoses that show signs of damage. Replace hose clamps that are cracked or damaged. Tighten or replace hose clamps which are loose.

Replace the Hoses and the Clamps

NOTICE

Care must be taken to ensure that fluids are contained during performance of inspection, maintenance, testing, adjusting, and repair of the product. Be prepared to collect the fluid with suitable containers before opening any compartment or disassembling any component containing fluids.

Refer to Special Publication, NENG2500, "Cat Dealer Service Tool Catalog" or refer to Special Publication, PECJ0003, "Cat Shop Supplies and Tools Catalog" for tools and supplies suitable to collect and contain fluids on Cat products.

Dispose of all fluids according to local regulations and mandates.

Cooling System

WARNING

Pressurized System: Hot coolant can cause serious burns. To open the cooling system filler cap, stop the engine and wait until the cooling system components are cool. Loosen the cooling system pressure cap slowly in order to relieve the pressure.

⚠ WARNING

Personal injury can result from removing hoses or fittings in a pressure system.

Failure to relieve pressure can cause personal injury.

Do not disconnect or remove hoses or fittings until all pressure in the system has been relieved.

1. Stop the engine.
2. Allow the engine to cool.
3. Before servicing a coolant hose, slowly loosen the filler cap for the cooling system in order to relieve any pressure.
4. Remove the filler cap for the cooling system.
5. Drain the coolant from the cooling system to a level that is below the hose that is being replaced. Drain the coolant into a suitable clean container. The coolant can be reused.
6. Remove the hose clamps.
7. Disconnect the old hose.
8. Replace the old hose with a new hose.
9. Install hose clamps which have been inspected or install new hose clamps. Refer to Specifications, SENR3130, "Torque Specifications", "Hose Clamps" for information about selecting and installing the proper hose clamps.
10. Refill the cooling system.
11. Clean the filler cap for the cooling system. Inspect the gaskets on the filler cap. Replace the filler cap if the gaskets are damaged. Install the filler cap.
12. Start the engine. Inspect the cooling system for leaks.

Fuel System

⚠ WARNING

Personal injury can result from removing hoses or fittings in a pressure system.

Failure to relieve pressure can cause personal injury.

Do not disconnect or remove hoses or fittings until all pressure in the system has been relieved.

⚠ WARNING

Contact with high pressure fuel may cause fluid penetration and burn hazards. High pressure fuel spray may cause a fire hazard. Failure to follow these inspection, maintenance and service instructions may cause personal injury or death.

NOTICE

Do not bend or strike high pressure lines. Do not install bent or damaged lines, tubes or hoses. Repair any loose or damaged fuel and oil lines, tubes and hoses. Leaks can cause fires. Inspect all lines, tubes and hoses carefully. Tighten all connections to the recommended torque.

NOTICE

Do not allow dirt to enter the fuel system. Thoroughly clean the area around a fuel system component that will be disconnected. Fit a suitable cover over any disconnected fuel system components.

Note: High-pressure fuel lines may be installed between the high-pressure fuel pump and the fuel injectors. High-pressure fuel lines are constantly charged with high pressure. Do not check the high-pressure fuel lines with the engine or the starting motor in operation. Wait for 10 minutes after the engine stops before you perform any service or repair on high-pressure fuel lines. Waiting for 10 minutes will allow the pressure to be purged.

1. Drain the fuel from the fuel system to a level that is below the hose that is being replaced.
2. Remove the hose clamps.
3. Disconnect the old hose.
4. Replace the old hose with a new hose.
5. Install hose clamps which have been inspected or install new hose clamps. Refer to Specifications, SENR3130, "Torque Specifications", "Hose Clamps" for information about selecting and installing the proper hose clamps.
6. Carefully inspect the engine for any spilled fuel. Make sure that no fuel remains on or close to the engine.

Note: Fuel must be added to the fuel system ahead of the fuel filter.

7. Refill the fuel system. Refer to this Operation and Maintenance Manual, "Fuel System - Prime" for information about priming the engine with fuel.
8. Start the engine. Inspect the fuel system for leaks.

Lubrication System

103865136

WARNING

Hot oil and hot components can cause personal injury. Do not allow hot oil or hot components to contact the skin.

1. Drain the oil from the lubrication system to a level that is below the hose that is being replaced.
2. Remove the hose clamps.
3. Disconnect the old hose.
4. Replace the old hose with a new hose.
5. Install hose clamps which have been inspected or install new hose clamps. Refer to Specifications, SENR3130, "Torque Specifications", "Hose Clamps" for information about selecting and installing the proper hose clamps.
6. Refill the lubrication system. Refer to this Operation and Maintenance Manual, "Engine Oil Level - Check" in order to ensure that the lubrication system is filled with the proper amount of engine oil.
7. Start the engine. Inspect the lubrication system for leaks.

Air System

1. Remove the hose clamps.
2. Disconnect the old hose.
3. Replace the old hose with a new hose.
4. Install hose clamps which have been inspected or install new hose clamps. Refer to Specifications, SENR3130, "Torque Specifications", "Hose Clamps" for information about selecting and installing the proper hose clamps.

Note: The bellows and the V-clamps that are used on the bellows should never be reused.

5. Start the engine. Inspect the air lines for leaks.

Overhaul (Major)

SMCS Code: 7595-020-MJ

Note: Fuel consumption in this Operation and Maintenance Manual, "Maintenance Interval Schedule" is based on a load factor of approximately 40 percent.

Refer to this Operation and Maintenance Manual in order to determine the maintenance interval for a major overhaul.

The need for a major overhaul is determined by several factors.

- An increase of oil consumption
- An increase of crankcase blowby
- The total amount of fuel consumption
- The service hours of the engine
- The wear metal analysis of the lube oil
- An increase in the levels of noise and vibration

An increase of wear metals in the lube oil indicates that the bearings and the surfaces that wear may need to be serviced. An increase in the levels of noise and vibration indicates that rotating parts require service.

Note: It is possible for oil analysis to indicate a decrease of wear metals in the lube oil. The cylinder liners may be worn so that polishing of the bore occurs. Also, the increased use of lube oil will dilute the wear metals.

Monitor the engine as the engine accumulates service hours. Consult your Caterpillar dealer about scheduling a major overhaul.

Note: The driven equipment may also require service when the engine is overhauled. Refer to the literature that is provided by the OEM of the driven equipment.

A major overhaul includes all of the work that is done for the top end overhaul and the general inspection. A major overhaul includes additional parts and labor. Additional parts and labor are required in order to completely rebuild the engine.

For the major overhaul, all of the bearings, seals, gaskets, and components that wear are disassembled. The parts are cleaned and inspected. If necessary, the parts are replaced. The crankshaft is measured for wear. The crankshaft may require regrounding. Alternatively, the crankshaft may be replaced with a Caterpillar replacement part.

Your Caterpillar dealer can provide these services and components. Your Caterpillar dealer can ensure that the components are operating within the appropriate specifications.

If you elect to perform an overhaul without the services of a Caterpillar dealer, be aware of the following recommendations.

Replacement of Components

Replace the following components during the major overhaul.

- Connecting rod bearings
- Crankshaft seals
- Crankshaft vibration damper
- Electronic fuel injectors
- Main bearings
- Piston rings
- Nonmetallic fuel lines (if equipped)

Inspection, Reconditioning or Exchanging of Components

Inspect the following components according to the instructions that are in Caterpillar reusability publications. Refer to Guidelines for Reusable Parts and Salvage Operations, SEBF8029, "Index of Publications on Reusability or Salvage of Used Parts".

Recondition the worn components or exchange the components, if necessary. Your Caterpillar dealer can provide these services and components.

- Camshaft followers
- Connecting rods
- Cylinder head assembly
- Cylinder liners
- Engine wiring harness

- Exhaust bellows
- Fuel transfer pump
- Oil pump
- Pistons
- Piston pins
- Prelube pump
- Spacer plate
- Turbochargers

Inspection of Components

Inspect the following components according to the instructions that are in Caterpillar reusability publications. Refer to Guidelines for Reusable Parts and Salvage Operations, SEBF8029, "Index of Publications on Reusability or Salvage of Used Parts".

- Camshaft
- Camshaft bearings
- Crankshaft
- Crankshaft thrust washers
- Driven equipment (alignment)
- Engine control module
- Front gear train
- Gear train bushings and bearings
- Rear gear train

Inspect the camshaft for damage to the journals and the lobes. Inspect the following components for signs of wear and/or for signs of fatigue:

- camshaft bearings
- camshaft followers

Inspect the crankshaft for any of the following conditions:

- deflection
- damage to the journals
- bearing material that has seized to the journals

Check the journal taper and the profile of the crankshaft journals. Check these components by interpreting the wear patterns on the following components:

- rod bearing
- main bearings

Note: If the crankshaft or the camshaft are removed for any reason, use the magnetic particle inspection process to check for cracks.

Replace the crankshaft vibration damper if any of the following conditions occur:

- Engine failure due to a broken crankshaft
- Excessive wear of the front bearing for the crankshaft
- Excessive wear of the gear train that is not caused by a lack of lubrication

Inspect the gears of the gear train and inspect the gear train bushings for the following conditions:

- Worn gear teeth
- Unusual fit
- Unusual wear

In addition to the inspection of components, inspect the alignment of the driven equipment. See the Application and Installation Guide for the engine or see the literature that is provided by the OEM of the driven equipment.

Cleaning of Components

Clean the oil cooler core and the aftercooler core. Then, pressure test both of these cores. For instructions on cleaning the cores, see this Operation and Maintenance Manual, "Aftercooler Core - Clean/Test" topic.

Clean the oil suction screen. Also, remove side covers in order to clean the oil sump. For instructions on removal and installation of components, see the Service Manual, "Disassembly and Assembly" module.

Obtain a Coolant Analysis

For conventional heavy-duty coolant or antifreeze, check the concentration of supplemental coolant additive (SCA) regularly. The concentration of SCA can be checked with an S·O·S coolant analysis (Level I). A more detailed coolant analysis is recommended periodically.

For example, considerable deposits are found in the water jacket areas on the external cooling system, but the concentrations of coolant additives were carefully maintained. The coolant probably contained minerals which were deposited on the engine over time.

A coolant analysis can be conducted in order to verify the condition of the water that is being used in the cooling system. A full water analysis may be obtained from the following sources:

- Caterpillar dealer
- Local water utility company
- Agricultural agent
- Independent laboratory

Caterpillar recommends an S·O·S coolant analysis (Level II). This is a comprehensive chemical evaluation of the coolant. This analysis is also a check of the overall condition of the inside of the cooling system. The following services are provided:

- Full Level I analysis
- Identification of the source of metal corrosion and of contaminants
- Identification of buildup of the impurities that cause corrosion
- Identification of buildup of the impurities that cause scaling
- Determination of possible electrolysis within the engines' cooling system

A report of the results of the analysis is provided. Maintenance recommendations are based on the results.

For more information about S·O·S coolant analysis, consult your Caterpillar dealer.

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Overhaul (Top End)

SMCS Code: 7595-020-TE

Note: Fuel consumption in this Operation and Maintenance Manual, "Maintenance Interval Schedule" is based on a load factor of approximately 40 percent.

A top end overhaul involves the removal, the inspection, and the rework of the cylinder head components. A few additional components are replaced and serviced.

Your Caterpillar dealer can provide these services and components. Your Caterpillar dealer can ensure that the components are operating within the appropriate specifications.

The following definitions explain the terminology for the services that are performed during an overhaul:

Inspect – Inspect the components according to the instructions that are in Caterpillar reusability publications. Refer to Special Publication, SEBF8029, "Index of Publications on Reusability or Salvage of Used Parts". The guidelines were developed in order to help Caterpillar dealers and customers to avoid unnecessary expenditures. New parts are not required if the existing parts can still be used, reconditioned, or repaired. If the components are not in the reusability guidelines, refer to the Service Manual, "Specifications" module.

Rebuild – The component is reconditioned in order to comply with reusability guidelines.

Replace – The service life of the part is exhausted. The part may fail before the next maintenance interval. The part must be replaced with a part that meets functional specifications. The replacement part may be a new part, a CAT remanufactured part, a rebuilt part, or a used part. Some worn components may be exchanged with your Caterpillar dealer for a credit on replacement parts. Consult your Caterpillar dealer about repair options for your engine.

If you elect to perform an overhaul without the services of a Caterpillar dealer, be aware of the recommendations in Table 10.

Table 10

Recommendations for Top End Overhauls ⁽¹⁾	
Service	Top End Overhaul
Inspect Rebuild Replace	Cylinder head assemblies
	Valves
Inspect Replace	Cylinder head assemblies
	Fuel injectors
	Rocker arms
	Valve bridges
Replace	Cylinder head gaskets Nonmetallic fuel lines (if equipped)

⁽¹⁾ For instructions on removal and installation of components, see the Service Manual, "Disassembly and Assembly" module.

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Overhaul Considerations

SMCS Code: 7595-043

Reduced hours of operation at full load will result in a lower average power demand. A decreased average power demand should increase both the engine service life and the overhaul interval.

The need for an overhaul is generally indicated by increased fuel consumption and by reduced power.

The following factors are important when a decision is being made on the proper time for an engine overhaul:

- The need for preventive maintenance
- The quality of the fuel that is being used
- The operating conditions
- The results of the S-O-S analysis

Oil Consumption as an Overhaul Indicator

Oil consumption, fuel consumption, and maintenance information can be used to estimate the total operating cost for your Caterpillar engine. Oil consumption can also be used to estimate the required capacity of a makeup oil tank that is suitable for the maintenance intervals.

Oil consumption is in proportion to the percentage of the rated engine load. As the percentage of the engine load is increased, the amount of oil that is consumed per hour also increases.

The oil consumption rate (brake specific oil consumption) is measured in grams per kW/h (lb per bhp). The brake specific oil consumption (BSOC) depends on the engine load. Consult your Caterpillar dealer for assistance in determining the typical oil consumption rate for your engine.

When an engine's oil consumption has risen to three times the original oil consumption rate due to normal wear, an engine overhaul should be scheduled. There may be a corresponding increase in blowby and a slight increase in fuel consumption.

Using Fuel Consumption for Calculating the Overhaul Intervals

Experience has shown that maintenance intervals are most accurately based on fuel consumption. Fuel consumption corresponds more accurately to the engine load. Table 11 lists average ranges of fuel consumption and service hours for a load factor of approximately 40 percent.

Table 11

Service Hours and Fuel Consumption for C27 and C32 Industrial and Locomotive Engines ⁽¹⁾		
	C27	C32
Top End Overhaul	9000 Service Hours	
	605670 L (160000 US gal) of fuel	662450 L (175000 US gal) of fuel
Major Overhaul	18000 Service Hours	
	1211330 L (320000 US gal) of fuel	1324890 L (350000 US gal) of fuel

⁽¹⁾ Fuel consumption is based on a load factor of approximately 40 percent.

Use the actual records of fuel consumption, when possible. If the actual records are not available, use the following procedure in order to estimate the fuel consumption.

1. Estimate the average percent of the load for the operation of the engine.
2. Refer to the fuel consumption data in the Technical Marketing Information (TMI) for your engine. This will determine the fuel consumption for the percent of the load that was estimated in Step 1. Use this figure as variable "F" for the equation in Table 12. For more information about the Technical Marketing Information (TMI) for your engine, consult your Caterpillar dealer.

Table 12

Equation For Calculating Overhaul Intervals
$F/R = H$
"F" is the estimated total amount of fuel consumption of the engine.
"R" is the rate of fuel consumption in liters per hour or gallons per hour.
"H" is the number of estimated hours until the overhaul interval.

Overhaul Options

Before Failure Overhaul

A planned overhaul before failure may be the best value for the following reasons:

- Costly unplanned downtime can be avoided.
- Many original parts can be reused according to the standards for reusable parts.
- The engine service life can be extended without the risk of a major catastrophe due to engine failure.
- The best cost/value relationship per hour of extended life can be attained.

After Failure Overhaul

If a major engine failure occurs and the engine must be removed, many options are available. An overhaul should be performed if the engine block or the crankshaft needs to be repaired.

If the engine block is repairable and/or the crankshaft is repairable, the overhaul cost should be between 40 percent and 50 percent of the cost of a new engine with a similar exchange core.

This lower cost can be attributed to three aspects:

- Specially designed Caterpillar engine features
- Caterpillar dealer exchange components
- Caterpillar Inc. remanufactured exchange components

Overhaul Recommendation

To minimize downtime, a scheduled engine overhaul by your Caterpillar dealer is recommended. This will provide you with the best cost/value relationship.

Note: Overhaul programs vary according to the engine application and according to the dealer that performs the overhaul. Consult your Caterpillar dealer for specific information about the available overhaul programs and about overhaul services for extending the engine life.

If an overhaul is performed without overhaul service from your Caterpillar dealer, be aware of the following maintenance recommendations.

Unit Fuel Injector

Clean the fuel injector body and replace the O-rings. Replace the O-rings and the gasket on the injector sleeve. Clean the area around the injector seating in the injector sleeve. Refer to the Service Manual for the complete procedure, or consult with your Caterpillar dealer for assistance.

Rebuild or Exchange

Cylinder Head Assembly, Connecting Rods, Pistons, Cylinder Liners, Turbocharger, Cylinder Packs, Oil Pump, and Fuel Transfer Pump

These components should be inspected according to the instructions that are found in various Caterpillar reusability publications. The Special Publication, SEBF8029 lists the reusability publications that are needed for inspecting the engine parts.

If the parts comply with the established inspection specifications that are expressed in the reusable parts guideline, the parts should be reused.

Parts that are not within the established inspection specifications should be dealt with in one of the following manners:

- Salvaging
- Repairing
- Replacing

Using out-of-spec parts can result in the following problems:

- Unscheduled downtime
- Costly repairs
- Damage to other engine parts
- Reduced engine efficiency
- Increased fuel consumption

Reduced engine efficiency and increased fuel consumption translates into higher operating costs. Therefore, Caterpillar Inc. recommends repairing out-of-spec parts or replacing out-of-spec parts.

Inspection and/or Replacement

Piston Rings, Crankshaft Bearings, Valve Rotators, and Crankshaft Seals

The following components may not last until the second overhaul.

- Thrust bearings
- Main bearings
- Rod bearings
- Valve rotators
- Crankshaft seals
- Nonmetallic fuel lines (if equipped)

Caterpillar Inc. recommends the installation of new parts at each overhaul period.

Inspect these parts while the engine is disassembled for an overhaul.

Inspect the crankshaft for any of the following conditions:

- Deflection
- Damage to the journals
- Bearing material that has seized to the journals

Check the journal taper and the profile of the crankshaft journals. Check these components by interpreting the wear patterns on the following components:

- Rod bearing
- Main bearings

Note: If the crankshaft is removed for any reason, use the magnetic particle inspection process to check for cracks in the crankshaft.

Inspect the camshaft for damage to the journals and to the lobes.

Note: If the camshaft is removed for any reason, use the magnetic particle inspection process to check for cracks in the camshaft.

Inspect the following components for signs of wear or for signs of scuffing:

- Camshaft bearings
- Camshaft followers

Caterpillar Inc. recommends replacing the crankshaft vibration damper.

Oil Cooler Core and Aftercooler Core

During an overhaul, the removal of the oil cooler core and the aftercooler core is recommended. The oil cooler core and the aftercooler core should be cleaned and pressure tested.

NOTICE

Do not use caustic cleaners to clean the core.

Caustic cleaners can attack the internal metals of the core and cause leakage.

Note: Use this cleaning procedure to clean the oil cooler core and the aftercooler core.

1. Remove the oil cooler core and the aftercooler core.
2. Remove any debris from the oil cooler core and the aftercooler core. To remove debris from the oil cooler core, turn the oil cooler core onto one end. To remove debris from the aftercooler core, turn the aftercooler core upside-down.
3. Flush the oil cooler core and the aftercooler core internally with cleaner in order to loosen foreign substances. This will also help to remove oil from the oil cooler core and the aftercooler core.

Note: The use of Hydrosolv Liquid Cleaners is recommended. Table 13 lists the Hydrosolv Liquid Cleaners that are available from your Caterpillar dealer.

Table 13

Hydrosolv Liquid Cleaners ⁽¹⁾		
Part Number	Description	Size
1U-5490	Hydrosolv 4165	19 L (5 US gallon)
174-6854	Hydrosolv 100	19 L (5 US gallon)

⁽¹⁾ Use a two to five percent concentration of the cleaner at temperatures up to 93°C (200°F). Refer to Application Guide, NEHS0526 or consult your Caterpillar dealer for more information.

4. Use steam to clean the oil cooler core and the aftercooler core. This removes any remaining residue from the cleaner. Flush the fins of the oil cooler core and the aftercooler core. Remove any other trapped debris.
5. Wash the oil cooler core and the aftercooler core with hot, soapy water. Rinse the oil cooler core and the aftercooler core thoroughly with clean water.

WARNING

Personal injury can result from air pressure.

Personal injury can result without following proper procedure. When using pressure air, wear a protective face shield and protective clothing.

Maximum air pressure at the nozzle must be less than 205 kPa (30 psi) for cleaning purposes.

6. Dry the oil cooler core and the aftercooler core with compressed air. Direct the air in the reverse direction of the normal flow.
7. Inspect the components in order to ensure cleanliness. The oil cooler core and the aftercooler core should be pressure tested. Repair the oil cooler core and the aftercooler core, if necessary. Install the oil cooler core and the aftercooler core.

For more information about cleaning the cores, consult your Caterpillar dealer.

Obtain Coolant Analysis

The concentration of supplemental coolant additive (SCA) should be checked regularly with test kits or with S·O·S Coolant Analysis (Level 1). Further coolant analysis is recommended when the engine is overhauled.

A coolant analysis can be conducted in order to verify the condition of the water that is being used in the cooling system. A full water analysis can be obtained by consulting your local water utility company or an agricultural agent. Private laboratories are also available for water analysis.

Caterpillar Inc. recommends an S·O·S Coolant Analysis (Level 2).

S·O·S Coolant Analysis (Level 2)

An S·O·S Coolant Analysis (Level 2) is a comprehensive coolant analysis which completely analyzes the coolant and the effects on the cooling system. An S·O·S Coolant Analysis (Level 2) provides the following information:

- Complete S·O·S Coolant Analysis (Level 2)
- Visual inspection of properties
- Identification of metal corrosion
- Identification of contaminants
- Identification of built up impurities (corrosion and scale)

S-O-S Coolant Analysis (Level 2) provides a report of the results of both the analysis and the maintenance recommendations.

For more information about coolant analysis, consult your Caterpillar dealer.

i04020194

Radiator - Clean

SMCS Code: 1353-070

Note: Adjust the frequency of cleaning according to the effects of the operating environment.

Inspect the radiator for these items: damaged fins, corrosion, dirt, grease, insects, leaves, oil, and other debris. Clean the radiator, if necessary.

WARNING

Personal injury can result from air pressure.

Personal injury can result without following proper procedure. When using pressure air, wear a protective face shield and protective clothing.

The maximum air pressure for cleaning purposes must be reduced to 205 kPa (30 psi) when the air nozzle is deadheaded.

Pressurized air is the preferred method for removing loose debris. Direct the air in the opposite direction of the air flow. Hold the nozzle approximately 6 mm (0.25 inch) away from the fins. Slowly move the air nozzle in a direction that is parallel with the tubes. This movement will remove debris that is between the tubes.

Pressurized water may also be used for cleaning. The maximum water pressure for cleaning purposes must be less than 275 kPa (40 psi). Use pressurized water in order to soften mud. Clean the core from both sides.

Use a degreaser and steam for removal of oil and grease. Clean both sides of the core. Wash the core with detergent and hot water. Thoroughly rinse the core with clean water.

After cleaning, start the engine and accelerate the engine to high idle rpm. This procedure will help in the removal of debris and drying of the core. Stop the engine. Use a light bulb behind the core in order to inspect the core for cleanliness. Repeat the cleaning, if necessary.

Inspect the fins for damage. Bent fins may be opened with a "comb". Inspect these items for good condition: welds, mounting brackets, air lines, connections, clamps, and seals. Make repairs, if necessary.

i02740889

Starting Motor - Inspect (If Equipped)

SMCS Code: 1451-040; 1453-040

Note: The OEM may be responsible for the starting motor for this engine application. Air starting motors are recommended if an explosive atmosphere may be present. If the starting motor is supplied by an OEM, refer to the Service Manual for the starter in order to locate additional information on the checking procedure and for specifications.

WARNING

The connection of battery cables to a battery and the disconnection of battery cables from a battery may cause an explosion which may result in injury or death. The connection and the disconnection of other electrical equipment may also cause an explosion which may result in injury or death. The procedures for the connection and the disconnection of battery cables and other electrical equipment should only be performed in a nonexplosive atmosphere.

If the starting motor fails, the engine may not start in an emergency situation. A scheduled inspection of the starting motor is recommended.

The starting motor pinion and the flywheel ring gear must be in good condition in order for the engine to start properly. The engine will not start if the starting motor pinion does not engage the flywheel ring gear. The teeth of the starting motor pinion and the flywheel ring gear can be damaged because of irregular engagement.

Inspect the starting motor for proper operation. Listen for grinding when the engine is started. Inspect the teeth of the starting motor pinion and the flywheel ring gear. Look for patterns of wear on the teeth. Look for teeth that are broken or chipped. If damaged teeth are found, the starting motor pinion and the flywheel ring gear must be replaced.

Electric Starting Motor

Note: Problems with the electric starting motor can be caused by the following conditions: malfunction of the solenoid and malfunction of the electric starting system.

Inspect the electrical system for the following conditions:

- Loose connections
- Corrosion
- Wires that are worn or frayed
- Cleanliness

Make repairs, if necessary.

Removal and Installation of the Starting Motor

Refer to the Service Manual, "Disassembly and Assembly" module for information on removing the starting motor and installing the starting motor.

Consult your Caterpillar dealer for assistance.

i01539769

Turbocharger - Inspect

SMCS Code: 1052-040

Periodic inspection and cleaning is recommended for the turbocharger compressor housing (inlet side). Any fumes from the crankcase are filtered through the air inlet system. Therefore, by-products from oil and from combustion can collect in the turbocharger compressor housing. Over time, this buildup can contribute to loss of engine power, increased black smoke and overall loss of engine efficiency.

If the turbocharger fails during engine operation, damage to the turbocharger compressor wheel and/or to the engine may occur. Damage to the turbocharger compressor wheel can cause additional damage to the pistons, the valves, and the cylinder head.

NOTICE

Turbocharger bearing failures can cause large quantities of oil to enter the air inlet and exhaust systems. Loss of engine lubricant can result in serious engine damage.

Minor leakage of a turbocharger housing under extended low idle operation should not cause problems as long as a turbocharger bearing failure has not occurred.

When a turbocharger bearing failure is accompanied by a significant engine performance loss (exhaust smoke or engine rpm up at no load), do not continue engine operation until the turbocharger is repaired or replaced.

An inspection of the turbocharger can minimize unscheduled downtime. An inspection of the turbocharger can also reduce the chance for potential damage to other engine parts.

Note: Turbocharger components require precision clearances. The turbocharger cartridge must be balanced due to high rpm. Severe Service Applications can accelerate component wear. Severe Service Applications require more frequent inspections of the cartridge.

Removal and Installation

For options regarding the removal, installation, repair and replacement, consult your Caterpillar dealer. Refer to the Service Manual for this engine for the procedure and specifications.

Cleaning and Inspecting

1. Remove the exhaust outlet piping and remove the air inlet piping from the turbocharger. Visually inspect the piping for the presence of oil. Clean the interior of the pipes in order to prevent dirt from entering during reassembly.
2. Turn the compressor wheel and the turbine wheel by hand. The assembly should turn freely. Inspect the compressor wheel and the turbine wheel for contact with the turbocharger housing. There should not be any visible signs of contact between the turbine wheel or compressor wheel and the turbocharger housing. If there is any indication of contact between the rotating turbine wheel or the compressor wheel and the turbocharger housing, the turbocharger must be reconditioned.

3. Check the compressor wheel for cleanliness. If only the blade side of the wheel is dirty, dirt and/or moisture is passing through the air filtering system. If oil is found only on the back side of the wheel, there is a possibility of a failed turbocharger oil seal.

The presence of oil may be the result of extended engine operation at low idle. The presence of oil may also be the result of a restriction of the line for the inlet air (plugged air filters), which causes the turbocharger to slobber.

4. Use a dial indicator to check the end clearance on the shaft. If the measured end play is greater than the Service Manual specifications, the turbocharger should be repaired or replaced. An end play measurement that is less than the minimum Service Manual specifications could indicate carbon buildup on the turbine wheel. The turbocharger should be disassembled for cleaning and for inspection if the measured end play is less than the minimum Service Manual specifications.
5. Inspect the bore of the turbine housing for corrosion.
6. Clean the turbocharger housing with standard shop solvents and a soft bristle brush.
7. Fasten the air inlet piping and the exhaust outlet piping to the turbocharger housing.

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Walk-Around Inspection

SMCS Code: 1000-040

Inspect the Engine for Leaks and for Loose Connections

A walk-around inspection should only take a few minutes. When the time is taken to perform these checks, costly repairs and accidents can be avoided.

For maximum engine service life, make a thorough inspection of the engine compartment before starting the engine. Look for items such as oil leaks, coolant leaks, exhaust leaks, loose bolts, worn belts, loose connections and trash buildup. Make repairs, as needed:

- The guards must be in the proper place. Repair damaged guards or replace missing guards.
- Wipe all caps and plugs before the engine is serviced in order to reduce the chance of system contamination.

NOTICE

For any type of leak (coolant, lube, or fuel) clean up the fluid. If leaking is observed, find the source and correct the leak. If leaking is suspected, check the fluid levels more often than recommended until the leak is found or fixed, or until the suspicion of a leak is proved to be unwarranted.

NOTICE

Accumulated grease and/or oil on an engine or deck is a fire hazard. Remove this debris with steam cleaning or high pressure water.

Note: Use care when you use steam cleaning. Use care when you use high pressure water. Direct spray to rotating electrics or electronic components can cause nonfixable damage.

NOTICE

Water and/or condensation can cause damage to electrical components. Protect all electrical components from exposure to water.

- Ensure that the coolant lines are properly clamped. Ensure that the fittings are tight. Check for leaks. Check the condition of all pipes.
- Inspect the water pump for coolant leaks.

Note: The water pump seal is lubricated by coolant in the cooling system. It is normal for a small amount of leakage to occur as the engine cools down and the parts contract.

Excessive coolant leakage may indicate the need to replace the water pump seal. For the removal of water pump and the installation of water pump and/or seals, refer to the Service Manual for the engine or consult your Caterpillar dealer.

- Inspect the lubrication system for leaks at the following locations: front crankshaft seal, rear crankshaft seal, oil pan, oil filters, valve cover, turbocharger, external oil lines, and connections.
- Inspect the fuel system for leaks. Look for loose fuel line clamps or connections.
- Inspect the piping for the air inlet system and the elbows for cracks and for loose clamps or connections.
- Ensure that the exhaust system is properly clamped. Ensure that the connections are tight. Check for leaks. Check the condition of all connections and components of the exhaust system.

- Inspect the alternator belt and the accessory drive belts for cracks, breaks or other damage.

Belts for multiple groove pulleys must be replaced as matched sets. If only one belt is replaced, the belt will carry more load than the belts that are not replaced. The older belts are stretched. The additional load on the new belt could cause the belt to break.

- Drain the water and the sediment from fuel tanks on a daily basis in order to ensure that only clean fuel enters the fuel system.
- Inspect the wiring and the wiring harnesses for loose connections and for worn wires or frayed wires.
- Inspect the ground strap for a good connection and for good condition.
- Inspect the engine-to-frame ground strap for a good connection and for good condition.
- Disconnect any battery chargers that are not protected against the current drain of the starting motor. Check the condition and the electrolyte level of the batteries, unless the engine is equipped with a maintenance free battery.
- Check the condition of the gauges. Replace any gauges which are cracked. Replace any gauges that can not be calibrated.

Visually inspect the water pump for leaks. If leaking of the water pump seals is observed, replace all of the water pump seals. Refer to two articles in the Disassembly and Assembly Manual, "Water Pump - Disassemble and Water Pump - Assemble" for the disassembly and assembly procedure. If it is necessary to remove the water pump, refer to two articles in the Disassembly and Assembly Manual, "Water Pump - Remove and Water Pump - Install".

Inspect the water pump for wear, cracks, pin holes and proper operation. Refer to the Parts Manual for the correct part numbers for your engine or consult your Caterpillar dealer if repair is needed or replacement is needed.

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Water Pump - Inspect

SMCS Code: 1361-040

A failed water pump might cause severe engine overheating problems that could result in the following conditions:

- Cracks in the cylinder head
- A piston seizure
- Other potential damage to the engine

A failed water pump might cause severe engine overheating problems that could result in cracks in the cylinder head, a piston seizure or other potential damage to the engine.

Warranty Section

Warranty Information

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Warranty Information

SMCS Code: 1000

Engine Protection Plans

Extended Warranties and Service Contracts

A wide variety of protection plans are available for Cat Engines. Consult your Cat dealer for detailed information on the specific programs and coverages that are available.

Consult your Cat dealer for information on a plan that is tailored in order to fit your requirements.

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Emissions Warranty Information

SMCS Code: 1000

This engine may be certified to comply with exhaust emission standards and gaseous emission standards that are prescribed by law at the time of manufacture, and this engine may be covered by an Emissions Warranty. A detailed explanation of the Emissions Warranty that is applicable to emissions certified engines is found in Supplement, SEBU6981, "Federal Emissions Control Warranty Information". Consult your authorized Caterpillar dealer to determine if your engine is emissions certified and if your engine is subject to an Emissions Warranty.

Reference Information Section

i00819749

Engine Ratings

i00727327

Engine Rating Conditions

SMCS Code: 1000

All engine ratings are in compliance with the following standard ambient air conditions of "SAE J1349":

- 99 kPa (29.3 inches of Hg)
- 30 percent relative humidity
- A temperature of 25 °C (77 °F)

Ratings relate to the standard conditions of "ISO8665", of "ISO3046/1", of "DIN6271", and of "BS5514".

The engine ratings are based on the following fuel specifications:

- Low heat value (LHV) of the fuel of 42 780 kJ/kg (18,390 Btu/lb) at 29 °C (84 °F)
- Gravity (API) of 35 degrees at 15 °C (60 °F)
- Specific gravity of .849 at 15 °C (60 °F)
- Density of 850 kg/m³ (7.085 lb/US gal)

The engine ratings are gross output ratings.

Gross Output Ratings – The total output capability of the engine that is equipped with standard accessories.

Standard accessories include the following components:

- Oil pumps
- Fuel pumps
- Water pumps

Subtract the power that is required to drive auxiliary components from the gross output. This will produce the net power that is available for the external load (flywheel).

Engine Rating Definitions

SMCS Code: 1000

It is important to know the use of the engine so that the rating will match the operating profile. The proper rating selection is also important so that the customer's perception of price and value is realized.

In selecting a rating for a specific application, the most important consideration is the time that is spent at full throttle. These rating definitions identify the percent of time at full throttle. The definitions also identify the corresponding times below rated rpm.

Note: The examples of the applications are only for reference. For an exact determination of the appropriate rating, follow the OEM specifications or consult your Caterpillar dealer.

A Rating – This rating is used for heavy-duty applications that are operated at rated load and at rated rpm up to 100 percent. This rating is used for engines that operate without interruption of load cycling. Typical applications include the following examples: pipeline pumping and ventilation.

B Rating – This rating is used when power and/or rpm are cyclic. The engine should be run at full load. The engine should not exceed 80 percent of the duty cycle. Typical applications include the following examples: irrigation, operation where normal pump demand is 85 percent of the engine rating, oil pumping/drilling, field mechanical pumping/drilling, and stationary/plant air compressors.

C Rating – This rating is used when power and/or rpm are cyclic. The horsepower and the rpm of the engine can be utilized continuously for one hour. This is followed by one hour of operation at the A rating or below the A rating. The engine should be run at full load. The engine should not exceed 50 percent of the duty cycle. Typical applications include the following examples: agricultural tractors, harvesters and combines, off-highway trucks, fire pumps, blast hole drills, rock crushers, wood chippers with high torque rise, and oil field hoisting.

D Rating – This rating is used when rated power is required for periodic overloads. The maximum horsepower and the rpm of the engine can be utilized continuously for a maximum of 30 minutes. This is followed by one hour of operation at the C rating. The engine should be run at full load. The engine should not exceed 10 percent of the duty cycle. Typical applications include the following examples: offshore cranes, runway snow blowers, water well drills, portable air compressors, and fire pump certification power.

E Rating – This rating is used when rated power is required for a short time for initial starting or for sudden overload. The rating is also used for emergency service when standard power is not available. The horsepower and the rpm of the engine can be utilized continuously for a maximum of 15 minutes. This is followed by one hour of operation at the C rating or by the duration of the emergency. The engine should be run at full load. The engine should not exceed 5 percent of the duty cycle. Typical applications include the following examples: standby centrifugal water pumps, oil field well servicing, crash trucks, portable air compressors, and gas turbine starting motors.

NOTICE

Operating engines above the rating definitions can result in shorter service life before overhaul.

Customer Service

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Customer Assistance

SMCS Code: 1000; 4450

USA and Canada

When a problem arises concerning the operation or the service of an engine, the problem will normally be managed by the dealer in your area.

Your satisfaction is a primary concern to Caterpillar and to Caterpillar dealers. If you have a problem that has not been handled to your complete satisfaction, follow these steps:

1. Discuss your problem with a manager from the dealership.
2. If your problem cannot be resolved at the dealer level, use the phone number that is listed below to talk with a Field Service Coordinator:

1-800-447-4986

The normal hours are from 8:00 to 4:30 Monday through Friday Central Standard Time.

3. If your needs have not been met still, submit the matter in writing to the following address:

Caterpillar Inc.
Manager, Customer Service, Engine Division
Mossville Bldg AC
P.O. Box 610
Mossville, Illinois 61552-0610

Please keep in mind: probably, your problem will ultimately be solved at the dealership, using the dealership facilities, equipment, and personnel. Therefore, follow the steps in sequence when a problem is experienced.

Outside of the USA and of Canada

If a problem arises outside the USA and outside Canada, and if the problem cannot be resolved at the dealer level, consult the appropriate Caterpillar office.

Latin America, Mexico, Caribbean
Caterpillar Americas Co.
701 Waterford Way, Suite 200
Miami, FL 33126-4670
USA
Phone: 305-476-6800
Fax: 305-476-6801

Europe, Africa, and Middle East
Caterpillar Overseas S.A.
76 Route de Frontenex
P.O. Box 6000
CH-1211 Geneva 6
Switzerland
Phone: 22-849-4444
Fax: 22-849-4544

Far East
Caterpillar Asia Pte. Ltd.
7 Tractor Road
Jurong, Singapore 627968
Republic of Singapore
Phone: 65-662-8333
Fax: 65-662-8302

China
Caterpillar China Ltd.
37/F., The Lee Gardens
33 Hysan Avenue
Causeway Bay
G.P.O. Box 3069
Hong Kong
Phone: 852-2848-0333
Fax: 852-2848-0440

Japan
Shin Caterpillar Mitsubishi Ltd.
SBS Tower
10-1, Yoga 4-Chome
Setagaya-Ku, Tokyo 158-8530
Japan
Phone: 81-3-5717-1150
Fax: 81-3-5717-1177

Japan
Caterpillar Power Systems, Inc.
SBS Tower (14th floor)
4-10-1, Yoga
Setagaya-Ku, Tokyo 158-0097
Phone: 81-3-5797-4300
Fax: 81-3-5797-4359

Australia and New Zealand
Caterpillar of Australia Ltd.
1 Caterpillar Drive
Private Mail Bag 4
Tullamarine, Victoria 3043
Australia
Phone: 03-9953-9333
Fax: 03-9335-3366

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Ordering Replacement Parts

SMCS Code: 4450; 7567

 WARNING

When replacement parts are required for this product Caterpillar recommends using Caterpillar replacement parts or parts with equivalent specifications including, but not limited to, physical dimensions, type, strength and material.

Failure to heed this warning can lead to premature failures, product damage, personal injury or death.

Quality Caterpillar replacement parts are available from Caterpillar dealers throughout the world. Caterpillar dealers' parts inventories are up-to-date. The parts stocks include all of the parts that are normally needed to protect your Caterpillar engine investment.

When you order parts, please specify the following information:

- Part number
- Part name
- Quantity

If there is a question concerning the part number, please provide your dealer with a complete description of the needed item.

When a Caterpillar engine requires maintenance and/or repair, provide the dealer with all the information that is stamped on the Information Plate. This information is described in this Operation and Maintenance Manual (Product Information Section).

Discuss the problem with the dealer. Inform the dealer about the conditions of the problem and the nature of the problem. Inform the dealer about when the problem occurs. This will help the dealer in troubleshooting the problem and solving the problem faster.

Reference Materials

- Maintenance log

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Maintenance Records

SMCS Code: 1000; 4450

Caterpillar Inc. recommends the retention of accurate maintenance records. Accurate maintenance records can be used for the following purposes:

- Determine operating costs.
- Establish maintenance schedules for other engines that are operated in the same environment.
- Show compliance with the required maintenance practices and maintenance intervals.

Maintenance records can be used for a variety of other business decisions that are related to engine maintenance.

Maintenance records are a key element of a maintenance program that is well managed. Accurate maintenance records can help your Caterpillar dealer to fine tune the recommended maintenance intervals in order to meet the specific operating situation. This should result in a lower engine operating cost.

Records should be kept for the following items:

Fuel Consumption – A record of fuel consumption is essential in order to determine when the load sensitive components should be inspected or repaired. Fuel consumption also determines overhaul intervals.

Service Hours – A record of service hours is essential to determine when the speed sensitive components should be inspected or repaired.

Documents – These items should be easy to obtain, and these items should be kept in the engine history file. All of the documents should show this information: date, service hours, fuel consumption, unit number, and engine serial number. The following types of documents should be kept as proof of maintenance or repair for warranty:

Keep the following types of documents as proof of maintenance for warranty. Also, keep these types of documents as proof of repair for warranty:

- Dealer work orders and itemized bills
- Owner's repair costs
- Owner's receipts

Maintenance Log

Table 14

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Reference Material

SMCS Code: 1000; 4450

The following publications can be obtained from any Cat dealer.

Lubricants

- Data Sheet, NEHP6015, "Cat SPG (Special Purpose Grease)"
- Special Publication, PEHJ0191, "Cat S·O·S Fluid Analysis"
- Data Sheet, PEHJ0021, "Cat DEO (SAE 10W-30 and 15W-40)" (Eastern Hemisphere excluding Egypt, United Arab Emirates, and Saudi Arabia)
- Data Sheet, PEHJ0059, "Cat DEO (SAE 10W-30 and 15W-40)" (Western Hemisphere excluding Brazil)
- Special Publication, PEHP6001, "How To Take A Good Oil Sample"
- Data Sheet, PEHP0002, "Cat MPGM (Multi-Purpose Grease with Molybdenum)"
- Data Sheet, PEHP7062, "Cat DEO SYN (SAE 5W-40)" (Worldwide, data sheet only available electronically through www.cat.com)
- Special Publication, PELJ0179, "Caterpillar Engine Crankcase Fluid-1 Specifications (Cat ECF-1)" (All international markets)
- Special Publication, SEBU5898, "Cold Weather Recommendations"

Coolants

- Special Publication, PEHJ0191, "Cat S·O·S Fluid Analysis"
- Special Publication, PEEP5027, "Label - ELC Radiator Label"
- Data Sheet, PEHP0067, "Cat ELC (Extended Life Coolant)"
- Data Sheet, PEHP9554, "Cat DEAC (Diesel Engine Antifreeze/Coolant)"
- Special Publication, SEBD0518, "Know Your Cooling System"

Miscellaneous

- Service Manual, RENR9795, "C27 and C32 Industrial Engines"
- Parts Manual, SEBP4150, "C32 Industrial Engine"
- Special Instruction, SEHS9031, "Storage Procedure for Caterpillar Products"
- Special Instruction, SEHS7332, "Warning Tag - Do Not Operate"
- Special Instruction, SEHS7633, "Battery Test Procedure"
- Special Publication, NENG2500, "Caterpillar Dealer Service Tool Catalog"
- Special Publication, SEBF8029, "Index to Guidelines for Reusable Parts and Salvage Operations"
- Special Publication, SEBF8062, "Guideline for Reusable Parts - Cleaning and Inspection of Air Filters"
- Specifications, SENR3130, "Torque Specifications"
- Special Publication, SEBU6251, "Caterpillar Commercial Diesel Engine Fluids Recommendations"
- Special Publication, PECP9067, "One Safe Source"

Additional Reference Material

The "Engine Fluids Data Book" can be obtained from the following locations: local technological society, local library, and local college. If necessary, consult EMA at the following address:

Engine Manufacturers Association
Two North LaSalle Street, Suite 2200
Chicago, IL, USA 60602
E-mail: ema@enginemanufacturers.org
Telephone: (312) 827-8700
Facsimile: (312) 827-8737

The "Society of Automotive Engineers (SAE) Specifications" can be found in your SAE handbook. This publication can also be obtained from the following locations: local technological society, local library, and local college. If necessary, consult SAE at the following address:

SAE International
400 Commonwealth Drive
Warrendale, PA, USA 15096-0001
Telephone: (724) 776-4841

The "American Petroleum Institute Publication No. 1509" can be obtained from the following locations: local technological society, local library, and local college. If necessary, consult API at the following address:

American Petroleum Institute
1220 L St. N.W.
Washington, DC, USA 20005
Telephone: (202) 682-8000

The International Organization for Standardization (ISO) offers information and customer service regarding international standards and standardizing activities. ISO can also supply information on the following subjects that are not controlled by ISO: national standards, local standards, regulations, certification, and related activities. Consult the member of ISO in your country.

International Organization for Standardization
(ISO)
1, rue de Varembe
Case postale 56
CH-1211 Genève 20
Switzerland
Telephone: +41 22 749 01 11
Facsimile: +41 22 733 34 30
E-mail: central@iso.ch
web site: <http://www.iso.ch>

European classifications are established by the Conseil International Des Machines a Combustion (CIMAC) (International Council on Combustion Engines).

CIMAC Central Secretariat
Lyoner Strasse 18
60528 Frankfurt
Germany
Telephone: +49 69 6603 1567
Facsimile: +49 69 6603 1566

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Decommissioning and Disposal

SMCS Code: 1000

When the generator set is removed from service, local regulations for the generator set decommissioning will vary. Disposal of the generator set will vary with local regulations. Consult the nearest Cat dealer for additional information.

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Product and Dealer Information

Note: For product identification plate locations, see the section "Product Identification Information" in the Operation and Maintenance Manual.

Delivery Date: _____

Product Information

Model: _____

Product Identification Number: _____

Engine Serial Number: _____

Transmission Serial Number: _____

Generator Serial Number: _____

Attachment Serial Numbers: _____

Attachment Information: _____

Customer Equipment Number: _____

Dealer Equipment Number: _____

Dealer Information

Name: _____ Branch: _____

Address: _____

Dealer Contact

Phone Number

Hours

Sales: _____

Parts: _____

Service: _____

Recommended CAT storage battery:

Genset Models	Internal Part No	Number of Batteries	Battery Voltage	Minimum CCA
D13-4,D13-4S,D20-6,D20-6S,D25-8,D30-10,D25-8S,D30-8S	115-2421	1	12V	950
D40-6,D50-6,D60-6,D40-6S,D50-6S,60-8S,D80-6,D100-6,D60-6S,D80-2S,D100-6S	115-2421	1	12V	950
D125-6,D150-8,	115-2421	1	12V	950
D175-2	115-2421	2	12V	950

Field connection Lugs:

For UL Listed product, it is recommended that the installer use crimp type lugs that are UL Listed and sized suitable for the application.



Operation and Maintenance Manual

Cat Commercial Diesel Engine Fluids Recommendations

Special Publication For All 3500 Series, C175 Series and Smaller Commercial Diesel Engines

Important Safety Information

Most accidents that involve product operation, maintenance and repair are caused by failure to observe basic safety rules or precautions. An accident can often be avoided by recognizing potentially hazardous situations before an accident occurs. A person must be alert to potential hazards. This person should also have the necessary training, skills and tools to perform these functions properly.

Improper operation, lubrication, maintenance or repair of this product can be dangerous and could result in injury or death.

Do not operate or perform any lubrication, maintenance or repair on this product, until you have read and understood the operation, lubrication, maintenance and repair information.

Safety precautions and warnings are provided in this manual and on the product. If these hazard warnings are not heeded, bodily injury or death could occur to you or to other persons.

The hazards are identified by the "Safety Alert Symbol" and followed by a "Signal Word" such as "DANGER", "WARNING" or "CAUTION". The Safety Alert "WARNING" label is shown below.



The meaning of this safety alert symbol is as follows:

Attention! Become Alert! Your Safety is Involved.

The message that appears under the warning explains the hazard and can be either written or pictorially presented.

A non-exhaustive list of operations that may cause product damage are identified by "NOTICE" labels on the product and in this publication.

Caterpillar cannot anticipate every possible circumstance that might involve a potential hazard. The warnings in this publication and on the product are, therefore, not all inclusive. You must not use this product in any manner different from that considered by this manual without first satisfying yourself that you have considered all safety rules and precautions applicable to the operation of the product in the location of use, including site-specific rules and precautions applicable to the worksite. If a tool, procedure, work method or operating technique that is not specifically recommended by Caterpillar is used, you must satisfy yourself that it is safe for you and for others. You should also ensure that the product will not be damaged or become unsafe by the operation, lubrication, maintenance or repair procedures that you intend to use.

The information, specifications, and illustrations in this publication are on the basis of information that was available at the time that the publication was written. The specifications, torques, pressures, measurements, adjustments, illustrations, and other items can change at any time. These changes can affect the service that is given to the product. Obtain the complete and most current information before you start any job. Cat dealers have the most current information available.



When replacement parts are required for this product Caterpillar recommends using Cat replacement parts or parts with equivalent specifications including, but not limited to, physical dimensions, type, strength and material.

Failure to heed this warning can lead to premature failures, product damage, personal injury or death.

In the United States, the maintenance, replacement, or repair of the emission control devices and systems may be performed by any repair establishment or individual of the owner's choosing.



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Foreword

Literature Information

This manual should be stored in the literature storage area.

The information contained in this document is the most current information available for coolants, fuels, and lubricants. Refer to the Operation and Maintenance Manual for any special lubrication requirements for your engine.

Whenever a question arises regarding the engine, this publication, or the Operation and Maintenance Manual, please consult any Caterpillar dealer for the latest available information.

Safety

Refer to the Operation and Maintenance Manual for your engine for all safety information. Read and understand the basic safety precautions listed in the Safety Section. In addition to safety precautions, this section identifies the text and locations of safety signs used on the engine.

Read and understand the basic precautions listed in the Safety Section before operating or performing lubrication, maintenance and repair on this engine.

Maintenance

Refer to the Operation and Maintenance Manual for your engine to determine all maintenance requirements.

Maintenance Intervals

Use the Maintenance Interval Schedule in the Operation and Maintenance Manual for your engine to determine servicing intervals. The actual operating environment of the engine also governs the maintenance interval schedule. Therefore, under extremely severe, dusty, wet or freezing cold operating conditions, more frequent lubrication and maintenance than is specified in the Maintenance Interval Schedule may be necessary.

Extended Engine Oil Drains and Warranty

Failures that result from extended oil drain periods are not Caterpillar factory defects and therefore are not covered by Caterpillar's warranty. In addition, failures that result from not using the recommended oil type are not Caterpillar factory defects and therefore are not covered by Caterpillar's warranty.

Refer to the applicable Operation and Maintenance Manual for standard oil drain periods and to the Maintenance Section, "Lubricant Specifications" of this publication for engine oil type and viscosity grade recommendations.

To reduce the potential risk of failures associated with extended oil drain periods; it is recommended that oil drain intervals only be extended based on oil analysis, and subsequent engine inspections. Oil analysis alone does not provide an indication of the rate of formation of lacquer, varnish and/or carbon on pistons and other engine surfaces. The only accurate way to evaluate specific oil performance in a specific engine and application that utilizes extended oil drain periods is to observe the effects on the engine components. This involves tear-down inspections of engines that have run to their normal overhaul period with extended oil drain intervals. Following this recommendation will help ensure that excessive component wear does not take place in a given application.

NOTICE

Light loads, low hour accumulation, and excessive idling time can contribute to excessive water in the crankcase oil. Corrosive damage, piston deposits and increased oil consumption can also result. If oil analysis is not done or the results are ignored, the potential for corrosive damage and piston deposits increases. Refer to the appropriate Operation and Maintenance Manual for guidance.

Note: Failures that result from extended oil drain periods are not warrantable failures, regardless of use of this recommended procedure. Failures that result from extended engine oil drain periods are considered improper use under the warranty.

Aftermarket Products and Warranty

NOTICE

When auxiliary devices, accessories or consumables (filters, oil, additives, catalysts, fuel, etc.) made by other manufacturers are used on Caterpillar products, the Caterpillar warranty is not affected simply because of such use. Failures that result from the installation or usage of other manufacturers auxiliary devices, accessories or consumables, however, are not Caterpillar factory defects and therefore are NOT covered by Caterpillar's warranty.

Caterpillar is not in a position to evaluate the many auxiliary devices, accessories or consumables promoted by other manufacturers and their effect on Caterpillar products. Installation or use of such items is at the discretion of the customer who assumes ALL risks for the effects that result from this usage.

Furthermore, Caterpillar does not authorize the use of its trade name, trademark, or logo in a manner which implies our endorsement of these aftermarket products.

Maintenance Section

Lubricant Specifications

i04891112

Lubricant Information

SMCS Code: 1000; 1300; 7581

NOTICE

Every attempt is made to provide accurate, up-to-date information. By the use of this document, you agree that Caterpillar Inc. is not responsible for errors or omissions.

The information that is provided is the latest recommendations for Cat diesel engines that are covered by this Special Publication. This information supersedes all previous recommendations which have been published for Cat diesel engines that are covered by this Special Publication. Special fluids are required for some engines. These fluids will still be necessary in those engines. Refer to the applicable Operation and Maintenance Manual.

This publication is a supplement to the Operation and Maintenance Manual. This publication does not replace the engine-specific Operation and Maintenance Manuals.

NOTICE

These recommendations are subject to change without notice. Consult your local Cat dealer for the most up to date recommendations.

Failure to follow the recommendations found in this Special Publication can cause engine failures, shortened engine service life, and reduced engine performance.

In order to avoid potential damage to your Cat engine, only purchase Cat fluids and Cat filters through your Cat dealer or Cat authorized outlets. For a list of authorized Cat parts outlets in your area, consult your Cat dealer.

If you purchase what appear to be Cat fluids and/or Cat filters through other outlets/sources, you are at a very high risk of purchasing counterfeit ("look-alike") products.

Counterfeit or "look-alike" products may visually appear the same as the original Cat product. The product performance and internal quality will typically be very low.

Counterfeit or "look-alike" products have a very high likelihood of causing and/or allowing engine and/or machine compartment damage.

Many of the guidelines, recommendations, and requirements that are provided in this Special Publication are interrelated. Before using the provided information, The user is responsible to read this Special Publication and understand the information provided.

The user is responsible to follow all safety guidelines found in this Special Publication and in the engine Operation and Maintenance Manual when performing all recommended and/or required engine, engine systems, and/or machine maintenance.

For questions concerning the information presented in this Special Publication and/or in your product Operation and Maintenance Manual, and/or for additional guidelines and recommendations (including maintenance interval recommendations/requirements) consult your Cat dealer.

Commercial products that make generic claims of meeting "Cat" and/or "Cat" requirements without listing the specific Cat recommendations and/or requirements that are met may not provide acceptable performance. Reduced engine and/or machine fluid compartment life may result. Refer to this Special Publication and refer to the product Operation and Maintenance Manual for Cat fluids recommendations and/or requirements.

Use of fluids that do not meet at least the minimum performance recommendations and/or requirements may lead to lower compartment performance and/or compartment failure.

Problems/failures that are caused by using fluids that do not meet the minimum recommended and/or required performance level for the compartment are not warrantable by Caterpillar Inc.. The fluid manufacturer and customer are responsible.

When fluids made by other manufacturers are used on Cat products, the Cat warranty is not affected simply because of such use. Failures that result from the installation or usage of other manufacturer fluids, however, are not Cat factory defects and therefore are NOT covered by the Cat warranty. Cat is not in a position to evaluate the many fluids promoted by other manufacturers and the effect on Cat products. Installation or use of such items is at the discretion of the customer who assumes ALL risks for the effects that result from this usage.

Different brand oils may use different additive packages to meet the various engine performance category/specification requirements. For the best results, do not mix oil brands.

The overall performance of engine and machine compartments is dependent on the choice of the lubricants and on the maintenance and cleanliness practices. The choices include filtration products, contamination control, tank management, and general handling practices. Cat designed and produced filtration products offer optimal performance and system protection.

In order to obtain additional information on Cat designed and produced filtration products, refer to the "Reference Material" article, "Filters" and "Miscellaneous" topics in this Special Publication or consult your Cat dealer for assistance with filtration recommendations for your Cat machine.

Note: In order to help ensure the maximum expected compartment performance and life, use a fluid that meets Cat highest level of fluid performance as described in this Special Publication for the compartment. Using a fluid that is considered an acceptable, but lower performing option for typical applications, will provide lower performance. (ex: Where fluids meeting either Cat ECF-1-a, Cat ECF-2 or Cat ECF-3 are offered as an option in typical applications, in order to help ensure the maximum expected engine compartment performance and life, oil meeting the Cat ECF-3 specification must be used.)

NOTICE

Faulty engine coolant temperature regulators, or operating with light loads, short operation cycles, excessive idling, or operating in applications where normal operating temperature is seldom reached can contribute to excessive water in the crankcase oil. Corrosive damage, piston deposits, increased oil consumption, and other damage can result. If a complete oil analysis program is not followed or if the results are ignored, the potential for damage increases. Follow engine warmup recommendations provided in this Special Publication and/or given in your engine Operation and Maintenance Manual.

i04891124

Engine Oil

SMCS Code: 1348; 7581

This article contains engine crankcase fluid recommendations for all Cat 3500 Series, C175 Series, and smaller Direct Injection (DI) engines, marine engines, and Precombustion Chamber (PC) engines. Some exceptions may be noted. Most Cat medium and heavy-duty PC diesel engines were produced before 1991.

Exceptions to these recommendations are 3116 and 3126 Marine Engines with Mechanical Unit Injection (MUI). Refer to the section pertaining to these engines in this Special Publication.

Engine lubricants play multiple roles in engines. Appropriate lubricants offer the following:

- Provide lubrication to the moving components of the engine under a wide range of temperatures
- Keep the engine components clean and remove wear debris
- Remove heat from the lubricated components
- Neutralize acidic products due to combustion process
- Protect the engine from cavitation and foaming
- Protect the engine from corrosion and rust
- Control Oil Consumption
- Disperse/Solubilize Contaminants (Soot)
- Support the regulated engine emissions limits

Current lubricant formulations are more advanced and complex than previous formulations. Current lubricants are developed to support advanced engine technologies that have lower emissions while supporting the performance and durability of these engines.

High performance oils are produced and validated using industry standard tests, proprietary tests, field tests, and often prior experience with similar formulation. Cat high quality and high performance lubricants are validated based on these factors.

In order to provide optimal engine performance and life and comply with regulated emission reduction, use the recommended engine oil as provided in this special publication. Due to the significant variations in the quality and performance of commercially available oils, Cat recommends the use of Cat oils as detailed in this article.

Cat Diesel Engine Oils

Cat fluids have been developed and tested by Cat in order to provide the full performance and service life that has been designed and built into Cat engines. The quality of finished oil is dependent on the quality of the base stock, the quality of the additives, and the compatibility of the base stock and additives. Cat fluids are formulated of high quality refined oil base stocks and additives of optimal chemistry and quantity in order to provide high performance in engines and machine components. Cat fluids are used for factory fill of Cat engines and components and are offered by Cat dealers for service fills and as aftermarket products. Consult your Cat dealer for more information on these Cat fluids.

Cat recommends the use of the following lubricants in commercial engines covered by this Special Publication:

Table 1

Cat Lubricants		Viscosity Grade
Diesel Engine Oil-Ultra Low Sulfur (API CJ-4)	Cat DEO-ULS	SAE 15W-40
		SAE 10W-30
	Cat DEO-ULS SYN	SAE 5W-40
	Cat DEO Cold Weather	SAE 0W-40
Diesel Engine Oil (API CI-4/CI-4 PLUS and API CH-4)	Cat DEO	SAE 15W-40
		SAE 10W-30
Multi Application Engine Oil	Cat MAEO Plus (Non-Cat mixed fleets)	SAE 10W-40
Special Application Engine Oil	Cat SAEO (Specific applications only)	SAE 30
		SAE 40
Diesel Engine Oil	Cat DEO (3600 engines only)	SAE 40
Precombustion Chamber Oil	Cat PCO (Specific applications only)	SAE 40

Note: Additional Cat fluids may be available.

Note: Cat engine oils exceed the performance requirements of the respective API categories.

This information applies to Cat commercial engines. For more lubricant recommendations see the following Special Publications:

- Special Publication, SEBU6250, "Caterpillar Machine Fluids Recommendations"

- Special Publication, SEBU6385, "Caterpillar On-Highway Diesel Engine Fluids Recommendations"

- Special Publication, SEBU6400, "Caterpillar Gas Engine Fluids Recommendations"

- Special Publication, SEBU7003, "Caterpillar 3600 Series and C280 Series Diesel Engine Fluids Recommendations"

Always consult your Cat dealer in order to ensure that you have the current revision level of the publication.

Note: The optimal application of the lubricants is dependent on the oil quality and the maintenance practices. Such practices include contamination control, tank management, and general handling practices.

Cat Diesel Engine Oils Recommendations

Cat DEO-ULS and Cat DEO multigrade oils are the preferred oils for use in ALL Cat diesel engines that are covered by this Special Publication. Commercial alternative diesel engine oils are, as a group, second choice oils.

Table 2

Summary of Cat engine lubricants Recommendations/Requirements		
	Non-Road Tier 4 Certified	Non-Road Pre Tier 4 Certified
Preferred	Cat DEO-ULS	Cat DEO-ULS
		Cat DEO
Commercial Lubricants	Cat ECF-3/API CJ-4	Cat ECF-3/API CJ-4, Cat ECF-2, Cat ECF-1-a

Note: Each of the Cat ECF specifications provides increased performance over lower Cat ECF specifications. For example, Cat ECF-3 provides higher performance than Cat ECF-2 and Cat ECF-3 provides much higher performance than Cat ECF-1-a. Refer to table 3 for details.

For nonroad Tier 4 United States Environmental Protection Agency (U.S. EPA) certified engines that are equipped with aftertreatment devices refer to the specific section of this chapter.

Table 3

Cat Engine Crankcase Fluids (ECF) Definitions	
Cat Minimum Performance Requirement	Cat ECF Specifications Requirements
Cat ECF-3	API CJ-4 Oil Category performance requirements
Cat ECF-2	API CI-4 / CI-4 PLUS Oil Category performance requirements and Passing standard Cat C13 engine test per API requirements and Oils of sulfated ash > 1.50 percent are not allowed
Cat ECF-1-a	API CH-4 Oil Category performance requirements and For oils that are between 1.30 percent and 1.50 percent sulfated ash, passing one additional Cat 1P SCOTE test ("ASTM D6681") is required and Oils of sulfated ash > 1.50 percent are not allowed

Cat DEO-ULS exceeds the limits of API CJ-4 standard tests. Cat DEO exceeds the limits of API CI-4/CI-4PLUS and API CH-4. Cat DEO-ULS and Cat DEO are rigorously tested with full-scale proprietary Cat engine tests to ensure optimal protection of Cat diesel engines. The tests include the following: sticking of the piston rings, piston deposits, oil control tests, wear tests, and soot tests. Proprietary tests help ensure that Cat oils provide superior performance in Cat diesel engines.

There are significant variations in the quality and performance of commercially available oils.

For this reason, Cat recommends the Cat oils listed in Table 2 and the guidelines in Table 3.

NOTICE

Do not use single grade API CF oils or multigrade API CF oils in Cat Series 3500, Series C175 and smaller Direct Injection (DI) diesel engines. Single grade API CF oils (or oils that meet all the performance requirements of API CF category) may only be used in Cat Series 3600 and Series C280 diesel engines, and older Cat engines that have precombustion chamber (PC) fuel systems. Oils that are used in Cat Series 3600 and Series C280 diesel engines must also pass a 7000 field performance evaluation. Consult your Cat dealer for details.

Cat DEO-ULS multigrade and Cat DEO multigrade oils are formulated with the correct amounts and chemistry of various additives including detergents, dispersants, antioxidants, alkalinity, antifoam, viscosity modifiers, and others in order to provide superior performance in Cat diesel engines where recommended for use.

Use appropriate lubricating oils that are compatible with the engine certification and aftertreatment system and with the fuel sulfur levels. Refer to the oil recommendations for Tier 4 engines in this chapter and to "Diesel Fuel Sulfur Impacts" article of this "Fuels Specifications" section and to the "Lubricants Specifications" section of this Special Publication.

Cat DEO-ULS and Cat DEO are multigrade oils. The viscosity grades of these Cat oils are SAE 10W-30, SAE 15W-40, and SAE 0W-40 as detailed in table 1 in this article. Multigrade oils provide the correct viscosity for a broad range of operating temperatures. Multigrade oils provide the appropriate oil film thickness for moving engine components.

Cat DEO-ULS multigrade and Cat DEO multigrade oils can be used in other manufacturer diesel engines and in gasoline engines. Refer to the engine manufacturer literature for the recommended categories/specifications. Compare the categories/specifications to the specifications of Cat DEO-ULS multigrade and Cat DEO multigrade oils. The current industry standards for Cat DEO-ULS multigrade and Cat DEO multigrade oils are listed on the product labels. Also refer to the datasheets for the product.

Consult your Cat dealer for part numbers and for available sizes of containers.

Cat DEO-ULS multigrade exceeds the requirements of the following Cat Engine Crankcase Fluid (ECF) specifications: Cat ECF-1-a, Cat ECF-2, and Cat ECF-3. Cat DEO-ULS multigrade exceeds the performance requirements for the following API oil categories: API CJ-4, API CI-4, API CI-4 PLUS, API CH-4, and API CF (or oils that claim the performance requirements of API CF category). Cat DEO-ULS multigrade is compatible for use in engines equipped with aftertreatment devices.

Cat DEO multigrade exceeds the requirements of the following Cat Engine Crankcase Fluid (ECF) Specifications: Cat ECF-1-a and Cat ECF-2. Cat DEO multigrade exceeds the performance requirements for the following American Petroleum Institute (API) oil categories: API CI-4, API CI-4 PLUS, API CH-4, and API CF (or oils that claim the performance requirements of API CF category). The availability of Cat DEO multigrade exceeding the noted requirements will vary by region.

Cat multigrade oils exceed many of the performance requirements of other manufacturers of diesel engines. Therefore these oils are excellent choices for many mixed fleets. Refer to your engine manufacturer literature and requirements.

Note: API oil categories CG-4 and CF-4 are obsolete. The API (American Petroleum Institute) does not license these categories effective August 2009. Oils that claim API CG-4 and CF-4 are not recommended for Cat engines.

API oil category CF is obsolete. The API (American Petroleum Institute) does not license this category effective end of 2010. API does not validate the quality of API CF oils and does not allow the display of API symbol (also called API doughnut) with CF as highest claim on the oil container. Oils that claim the requirements of API CF can be used ONLY in Cat 3112 and Cat 3126 Marine Engines. Refer to the details given in the Marine engine section in this Special Publication.

Recommendation for Tier 4 Engines

Cat DEO-ULS or oils that meet the Cat ECF-3 specification and the API CJ-4 oil category are required for use in nonroad Tier 4 United States Environmental Protection Agency (U.S. EPA) certified engines that are equipped with aftertreatment devices.

Cat DEO-ULS or oils that meet the Cat ECF-3 specification and the API CJ-4 are required for use in the applications listed below. If oils meeting the Cat ECF-3 specification and the API CJ-4 specifications are not available, oils meeting ACEA E9 may be used. ACEA E9 oils meet the chemical limits designed to maintain aftertreatment device life. ACEA E9 oils are validated using some but not all ECF-3 and API CJ-4 standard engine performance tests. Consult your oil supplier when considering use of an oil that is not Cat ECF-3 or API CJ-4 qualified.

- Nonroad EU Stage IIIB and IV type-approved engines that are equipped with aftertreatment devices
- Nonroad Japan Step 4 approved engines that are equipped with aftertreatment devices

Refer to Table 2 for the order of preference of engine oils. Cat DEO-ULS and oils meeting the Cat ECF-3 specification and the API CJ-4 and ACEA E9 oil categories have the following chemical limits:

- 1 percent maximum sulfated ash
- 0.12 percent maximum phosphorous
- 0.4 percent maximum sulfur

The chemical limits were developed in order to maintain the expected aftertreatment devices life, performance, and service intervals. Use of oils other than Cat DEO-ULS or oils that do not meet the Cat ECF-3 specification and the API CJ-4 oil category (and/or ACEA E9 category for EU and Japan-specific applications listed above) in aftertreatment-equipped engines can negatively impact performance of the aftertreatment devices, can contribute to Diesel Particulate Filter (DPF) plugging and/or can cause the need for more frequent DPF ash service intervals. Refer to your engine-specific Operation and Maintenance Manual, and refer to your aftertreatment device documentation, if available, for additional guidance.

Typical aftertreatment systems include the following:

- Diesel Particulate Filters (DPF)
- Diesel Oxidation Catalysts (DOC)

- Selective Catalytic Reduction (SCR)
- Lean NOx Traps (LNT)

Other systems may apply.

Cat DEO-ULS and Cat DEO are recommended for all pre-Tier 4 engines that use Ultra Low Sulfur Diesel (ULSD) or Low Sulfur Diesel (LSD) fuels.

Cat DEO is recommended for engines using fuels of sulfur levels that exceed 0.1 0.2 percent (2000 ppm). Cat DEO-ULS may be used in these applications if an oil analysis program is followed. The oil change interval may be affected by the fuel sulfur level. Refer to Table 4 in this section of this Special Publication.

Note: For on-Highway engines fluids recommendations, refer to the Operation and Maintenance Manual of your engine and also refer to the most current revision level of Special Publication, SEBU6385, "Caterpillar On-Highway Diesel Engine Fluids Recommendations" or consult your Cat dealer.

Ultra Low Sulfur Diesel (ULSD) fuel 0.0015 percent (≤ 15 ppm (mg/kg)) sulfur is required by regulation for use in engines certified to nonroad Tier 4 standards (U.S. EPA Tier 4 certified). ULSD must also be used in engines equipped with exhaust aftertreatment systems.

European ULSD 0.0010 percent (≤ 10 ppm (mg/kg)) sulfur fuel is required by regulation for use in engines certified to European nonroad Stage IIIB and newer standards. European ULSD must also be used in engines equipped with exhaust aftertreatment systems.

Certain governments/localities and/or applications MAY require the use of ULSD fuel. Consult federal, state, and local authorities for guidance on fuel requirements for your area.

ULSD fuel or sulfur-free diesel fuel are applicable for use in all engines regardless of the engine Tier or Stage.

NOTICE

Do not add new engine oil, waste engine oil or any oil product to the fuel unless the engine is designed and certified to burn diesel engine oil (for example Caterpillar ORS designed for large engines). Caterpillar experience has shown that adding oil products to Tier 4 engine fuels (U.S. EPA Tier 4 certified), to Euro IV/Stage IV certified engine fuels, or to the fuels of engines equipped with exhaust aftertreatment devices, will generally cause the need for more frequent ash service intervals and/or cause loss of performance.

Adding oil products to the fuel may raise the sulfur level of the fuel and may cause fouling of the fuel system and loss of performance.

Commercial Oils

Commercial Crankcase Fluid Recommendations for all Current and Noncurrent Cat Diesel Engines that are covered by this Special Publication

Note: Non-Cat commercial oils are, as a group, second choice oils. Within this grouping of second choice oils there are tiered levels of performance.

NOTICE

Cat does not warrant the quality or performance of non-Cat fluids.

Cat developed the Engine Crankcase Fluid (ECF) specifications to ensure the availability of high performance commercial diesel engine oils.

There are three current Cat ECF specifications: Cat ECF-1-a, Cat ECF-2, and Cat ECF-3. Each higher Cat ECF specification provides increased performance over lower Cat ECF specifications. For example, Cat ECF-3 provides higher performance than Cat ECF-2 and Cat ECF-3 provides much higher performance than Cat ECF-1-a. Refer to table 3 for details.

API category oils that have not met the requirements of at least one Cat ECF specification may cause reduced engine life.

Note: The Cat ECF-3 specification was released in October 2006.

Oils that meet the API CJ-4 oil category requirements are Cat ECF-3 specification compliant.

Note: The Cat ECF-1-a and Cat ECF-2 specifications replaced the Cat ECF-1 specification as of 1 March 2007.

Note: Cat DEO and DEO-ULS are required to pass proprietary full-scale diesel engine testing. The testing is above and beyond the testing required by the various Cat ECF specifications and by the various API oil categories that are also met. This additional proprietary testing helps ensure that Cat multigrade diesel engine oils, when used as recommended, provide superior performance in Cat diesel engines. If Cat DEO multigrade or DEO-ULS multigrade oils are not used, use only commercial oils that meet the recommendations and requirements stated below:

When the recommended Cat DEO-ULS and Cat DEO diesel engine oils are not used, commercial oils that meet the requirements of the Cat ECF-1-a, Cat ECF-2, and/or the Cat ECF-3 specification are acceptable, but second choice, for use in Cat diesel engines that are covered by this Special Publication.

Cat DEO-ULS or oils that meet the Cat ECF-3 specification and the API CJ-4 oil category are required for use in nonroad Tier 4 United States Environmental Protection Agency (U.S. EPA) certified engines that are equipped with aftertreatment devices.

Note: For engines that are Tier 4 EPA certified, refer to the Recommendations for Tier 4 Engines article in this Engine Oil section.

For engines using fuels of sulfur levels that exceed 0.2 percent (2000 ppm), Cat recommends Cat DEO. However, commercial oils that meet Cat ECF-2 or Cat ECF-1-a specifications are acceptable. Commercial oils that meet Cat ECF-3 specifications may be used in these applications if an oil analysis program is followed. The oil change interval is affected by the fuel sulfur level. Refer to Table 4 in this section of this Special Publication.

Note: For on-Highway engines fluids recommendations, refer to the Operation and Maintenance Manual of your engine and also refer to the most current revision level of Special Publication, SEBU6385, "Caterpillar On-Highway Diesel Engine Fluids Recommendations" or consult your Cat dealer.

Note: In selecting oil for any engine application, both the oil viscosity and oil performance category/specification as specified by the engine manufacturer must be defined and satisfied. Using only one of these parameters will not sufficiently define oil for an engine application.

In order to make the proper diesel engine oil viscosity grade choice, refer to the "Lubricant Viscosities for Ambient Temperatures" table in this Special Publication.

NOTICE

Failure to follow these oil recommendations can cause shortened engine service life due to deposits and/or excessive wear.

NOTICE

Do not use single grade API CF oils or multigrade API CF oils in Cat Series 3500, Series C175 and smaller Direct Injection (DI) diesel engines. Single grade API CF oils (or oils that meet all the performance requirements of API CF category) may only be used in Cat Series 3600 and Series C280 diesel engines, and older Cat engines that have precombustion chamber (PC) fuel systems. Oils that are used in Cat Series 3600 and Series C280 diesel engines must also pass a 7000 field performance evaluation. Consult your Cat dealer for details.

NOTICE

Do not add new engine oil, waste engine oil or any oil product to the fuel unless the engine is designed and certified to burn diesel engine oil (for example Caterpillar ORS designed for large engines). Caterpillar experience has shown that adding oil products to Tier 4 engine fuels (U.S. EPA Tier 4 certified), to Euro IV/Stage IV certified engine fuels, or to the fuels of engines equipped with exhaust aftertreatment devices, will generally cause the need for more frequent ash service intervals and/or cause loss of performance.

Adding oil products to the fuel may raise the sulfur level of the fuel and may cause fouling of the fuel system and loss of performance.

Total Base Number (TBN) and Fuel Sulfur Levels for Direct Injection (DI) Diesel Engines

This article provides information for Direct Injection (DI) Diesel Engines, Precombustion Chamber (PC) Engines and Direct Injection (DI) 3116 and 3126 Marine Diesel Engines.

The use of Cat S·O·S Services oil analysis is recommended for determining oil life.

TBN is also commonly referred to as Base Number (BN).

The minimum required Total Base Number (TBN) for oil depends on the fuel sulfur level. For commercial diesel engines that use distillate fuel, the following guidelines apply:

Table 4

TBN recommendations for applications in Cat engines		
Fuel Sulfur Level percent (ppm)	Cat Engine Oils ⁽¹⁾	TBN of Commercial Engine Oils
0.05 percent (500ppm)	Cat DEO-ULS Cat DEO	Min 7
>0.05-0.2 percent (>500- 2000 ppm) ⁽²⁾	Cat DEO Cat DEO-ULS	Min 10
Above 0.2 percent (above 2000ppm) ⁽³⁾⁽⁴⁾	Cat DEO ⁽⁵⁾	Min 10

⁽¹⁾ Cat DEO-ULS applies to Cat DEO-ULS SAE 15W-40, SAE10W-30, Cat DEO-ULS SYN SAE 5W-40, and Cat DEO Cold Weather SAE 0W-40. Cat DEO applies to Cat DEO SAE 15W-40 and SAE 10W-30.

⁽²⁾ Use of an oil analysis program to determine oil drain intervals is strongly recommended if fuel sulfur is between 0.05% (500 ppm) and 0.5% (5000 ppm).

⁽³⁾ Use of an oil analysis program to determine oil drain intervals is required if fuel sulfur is above 0.5% (5000 ppm).

⁽⁴⁾ For fuels of sulfur levels that exceed 1.0 percent (10,000 ppm), refer to TBN and engine oil guidelines given in this section.

⁽⁵⁾ Cat DEO-ULS may be used if an oil analysis program is followed. High fuel sulfur levels may reduce the oil drain intervals.

Note: For PC (Precombustion Chamber) diesel engines, which are mainly 1990 and older engines, the minimum new oil TBN must be 20 times the fuel sulfur level.

For regions in the world where fuels of high sulfur that exceed 1.0 percent (10,000 ppm (mg/kg)) are available and allowed for use by law, use the following guidelines:

- Choose multigrade oil with the highest TBN that meets one of these specifications: Cat ECF-1-a, Cat ECF-2, or Cat ECF-3.
- Reduce the oil change interval. Base the oil change interval on the oil analysis. Ensure that the oil analysis includes the condition of the oil and a wear metal analysis. Cat S·O·S Services oil analysis is required.

TBN testing is an optional part of the SOS Services oil analysis program. TBN testing may be done in addition to the standard SOS Services tests for oil deterioration. In most applications, the SOS Services tests for oxidation, sulfation, viscosity, and wear will identify oil deterioration.

TBN of the oil is typically measured using "ASTM D2896" and/or "ASTM D4739" test methods. Both methods can be used to measure the TBN of used oils. However, "ASTM D4739" is the preferred method for used oils.

- Consider changing the oil if the "ASTM D2896" test result reaches 4 TBN. Look for other signs of oil deterioration, or abnormal wear to verify the need to change oil.
- Consider changing the oil if the "ASTM D4739" test result reaches 3 TBN. Look for other signs of oil deterioration, or abnormal wear to verify the need to change oil.

- Be aware that both of these test methods have variability of approximately ± 1 TBN. Care should be taken when analyzing the results of the TBN test. Consult a trained S·O·S Services analyst when making oil drain decisions based on oil sample results.

Note: The use of Cat S·O·S Services oil analysis helps environmental sustainability as the best way to optimize oil life. The service will help engines reach the expected life. Consult your Cat dealer regarding the testing required to establish a safe, optimized oil drain interval.

In order to help protect your engine, and optimize oil drain intervals for engine applications and duty cycles, use Cat S·O·S Services oil analysis as follows:

- Recommended as a matter of course
- Recommended in order to determine oil drain intervals when operating on fuel with sulfur levels between 0.05% (500 ppm) and 0.5% (5000 ppm)
- Required in order to determine oil drain intervals when operating on fuel with sulfur levels that are above 0.5% (5000 ppm)

Note: Engine operating conditions play a key role in determining the effect that fuel sulfur will have on engine deposits and on engine wear. Consult your Cat dealer for guidance when fuel sulfur levels are above 0.1% (1000 ppm).

Excessive piston deposits can be produced by oil with a high TBN and/or high ash. These deposits can lead to a loss of control of the oil consumption and to the polishing of the cylinder bore.

There are many factors that contribute to rapid TBN depletion, a not all inclusive list follows:

- High sulfur fuel (The more fuel sulfur, the more rapid the TBN depletion.)
- Faulty engine coolant regulators
- Light loads
- Short operation cycles
- Excessive idling
- Operating in applications where normal operating temperature is seldom reached
- High humidity (allowing excessive condensation)

Bullets 2 through 7 above can contribute to excessive water in the crankcase oil. The water combines with available sulfur to form sulfuric acid. Neutralizing acids that are formed contribute to rapid TBN depletion.

NOTICE

Depending on application severity and localized environmental conditions, and also depending on maintenance practices, operating Direct Injection (DI) diesel engines and operating PC (Precombustion Chamber) diesel engines on fuel with sulfur levels over 0.1 percent (1000 ppm) may require significantly shortened oil change intervals in order to help maintain adequate wear protection. Refer to this Special Publication, "Fuel Specifications" section, "Diesel Fuel Sulfur" topic for additional information.

Note: Do NOT use only this Special Publication as a basis for determining oil drain intervals.

This Special Publication does not address recommended oil drain intervals, but rather provides guidance that should be used with your specific engine/machine Operation and Maintenance Manuals in determining acceptable oil drain intervals. Consult your engine/machine Operation and Maintenance Manuals, and consult your Cat dealer for additional guidance, including but not limited to guidance on establishing optimized and/or acceptable oil drain intervals.

Severe applications

An engine which operates outside of normal conditions is operating in a severe service application.

An engine that operates in a severe service application may need more frequent maintenance intervals in order to maximize the following conditions:

- Reliability

- Service life

Severe Applications Require the Use of Higher Performing Diesel Engine Oils. Examples of severe duty applications include, but not limited to the following:

- operating at greater than 75% load factor
- operating in high humidity
- operating with fuel sulfur levels that are above 0.1% (1000 ppm)

In order to help ensure the maximum expected compartment performance and life, higher performing fluids as described in this Special Publication may be required. Fluids that meet only the minimum performance levels may be allowed for typical applications, but maintenance intervals must be reduced. For the maximum expected engine compartment performance and life and where LSD or ULSD fuels are available, oils meeting the Cat ECF-3 specification must be used.

The number of individual applications cause the impossibility of identifying all of the factors which may contribute to severe service operation. Consult your Cat dealer for the unique maintenance that may be necessary for your engine.

An application is a severe service application if any of the following conditions apply:

Severe Environmental Factors

- Frequent operation in dirty air
- Frequent operation at an altitude which is above 1525 m (5000 ft)
- Frequent operation in ambient temperatures which are above 32° C (90° F)
- Frequent operation in ambient temperatures which are below 0° C (32° F)

Severe Operating Conditions

- Frequent operation with inlet air which has a corrosive content
- Operation with inlet air which has a combustible content
- Operation which is outside of the intended application
- Operation with a plugged fuel filter

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- Extended operation at low idle (more than 20% of hours)
- Frequent cold starts at temperatures below 0° C (32° F)
- Frequent dry starts (starting after more than 72 hours of shutdown)
- Frequent hot shutdowns (shutting down the engine without the minimum of 2 minutes to 5 minutes of cool down time)
- Operation above the engine rated speed
- Operation below the peak torque speed
- Operating with fuel which does not meet the standards for distillate diesel fuel as stated in Special Publication, SEBU6250, "Caterpillar Machine Fluids Recommendations", "Distillate Diesel Fuel"
- Operating with a blend of distillate fuel which contains more than 20 percent biodiesel

Improper Maintenance Procedures (Maintenance Procedures Which May Contribute to a Severe Service Application)

- Inadequate maintenance of fuel storage tanks from causes such as excessive water, sediment, and microorganism growth.
- Extending maintenance intervals beyond the recommended intervals
- Using fluids which are not recommended in Special Publication, SEBU6250, "Caterpillar Machine Fluids Recommendations"
- Extending maintenance intervals for changing the engine oil and engine coolant without S-O-S validation
- Extending maintenance intervals for changing air filters, oil filters, and fuel filters
- Failure to use a water separator
- Using filters which are not recommended by Special Publication, PEWJ0074, "2008 Cat Filter and Fluid Application Guide"
- Storing the engine for more than 3 months but less than 1 yr (For information about engine storage, refer to Special Publication, SEHS9031, "Storage Procedure for Caterpillar Products")

Engine Oil (3116 and 3126 Marine Engines)

SMCS Code: 1348; 7581

Recommendations

Cat does not recommend the use of multigrade oils in the 3116 and 3126 Marine Diesel Engines that use mechanical unit injection (MUI).

Multigrade oils use high molecular weight polymers as viscosity index improvers. When the crankcase blowby flows through the turbocharger and the aftercooler, the viscosity index improvers can adhere to the turbocharger compressor and aftercooler core.

The fouling of the turbocharger and aftercooler can cause reduced air flow, loss of power, and increased black smoke. The emission of black smoke results in buildup of soot on the transom of the boat.

Note: Cat recommends the use of single grade oils that pass all API CF-4 category requirements unless crankcase blowby has been routed away from the air cleaner inlet.

Cat SAEO (Special Application Engine Oil)

Note: Cat SAEO is recommended for use in Cat 3116 and 3126 Marine Diesel Engines with mechanical unit injection. 3116 and 3126 Marine Diesel Engines that begin with the following serial number prefixes are included: (S/N: 6SR), (S/N: 8NM), (S/N: 4KG), (S/N: 1SK), (S/N: 1ZJ), (S/N: 6MK), and (S/N: 4EZ).

The factory-fill for 3116 and 3126 Marine Engines is Cat SAEO with the following properties:

- Meets all requirements of API CF-4 category
- Viscosity grade of SAE 30

For maximum performance in 3116 and 3126 Marine Diesel Engines with mechanical unit injection, Cat recommends the following engine oil:

- Cat SAEO (SAE 30)
- Cat SAEO (SAE 40)

Commercial Oils (3116 and 3126 Marine Engines)

NOTICE

Cat does not warrant the quality or performance of non-Cat fluids.

When Cat SAEO is not used, use the following commercial oils:

- Single grade oil with a viscosity of SAE 30 or SAE 40 that meets all API CF category requirements is preferred.
- Single grade oil with a viscosity of SAE 30 or SAE 40 with an API CF additive package and no viscosity improvers is acceptable oil.

API oil category CF is obsolete. The API (American Petroleum Institute) does not license this category effective end of 2010. API does not validate the quality of API CF oils and does not allow the display of API symbol (also called API doughnut) with CF as highest claim on the oil container.

Oil products that used to be licensed as API CF oil performance category and have not changed formulation are acceptable for use in Cat 3116 and 3126 marine engines.

For an acceptable commercial single grade oil, consult your Cat dealer.

Some commercial oils that meet the requirements API CF-4 category may require reduced oil change intervals. To determine the oil change interval, closely monitor the condition of the oil and perform a wear metal analysis. Cat S·O·S Services oil analysis program is the preferred method.

NOTICE

Failure to follow these oil recommendations can cause shortened engine service life due to deposits and/or excessive wear.

Total Base Number (TBN) and Fuel Sulfur Levels for Direct Injection (DI) Diesel Engines (3116 and 3126 Marine Engines)

This article provides information for 3116 and 3126 Marine Diesel Engines.

The use of Cat S·O·S Services oil analysis program is recommended for all lubricating fluids.

TBN is also commonly referred to as Base Number (BN).

The minimum required Total Base Number (TBN) for oil depends on the fuel sulfur level. For 3116 and 3126 Marine Diesel Engines that use distillate fuel, the following guidelines apply:

- For fuel sulfur levels of up to 1.0 percent (10,000 ppm sulfur), use a recommended single grade engine oil of TBN that is double the fuel sulfur level at a minimum. Example: Minimum TBN of the engine oil = Fuel sulfur level percent x 2.
- For fuel sulfur levels of 1.0 percent (10,000 ppm sulfur) or higher, choose a recommended single grade engine oil, and follow the relevant information given in this article.

Note: The typical units used to express sulfur concentration are: parts per million (ppm), mg/kg or percent. The two units ppm and mg/kg are equivalent. In order to convert fuel sulfur level from ppm or mg/kg to percent, divide the ppm or mg/kg value by 10,000. Example:

- Fuel of sulfur level 500 ppm is 0.05 percent sulfur ($500 / 10,000 = 0.05$)
- Fuel of sulfur level 1000 ppm is 0.1 percent sulfur ($1000 / 10,000 = 0.1$)

For regions in the world where fuels of high sulfur that exceed 1.0 percent (10,000 ppm (mg/kg)) are available and allowed for use by law, use the following guidelines:

- Choose a recommended single grade oil with the highest TBN.
- Reduce the oil change interval. Base the oil change interval on the oil analysis. Ensure that the oil analysis includes the condition of the oil and a wear metal analysis. Cat S·O·S Services oil analysis is required.

TBN testing is an optional part of the SOS Services oil analysis program. TBN testing may be done in addition to the standard SOS Services tests for oil deterioration. In most applications, the SOS Services tests for oxidation, sulfation, viscosity, and wear will identify oil deterioration.

TBN of the oil is typically measured using "ASTM D2896" and/or "ASTM D4739" test methods. Both methods can be used to measure the TBN of used oils. However, "ASTM D4739" is the preferred method for used oils.

- Consider changing the oil if the "ASTM D2896" test result reaches 4 TBN. Look for other signs of oil deterioration, or abnormal wear to verify the need to change oil.
- Consider changing the oil if the "ASTM D4739" test result reaches 3 TBN. Look for other signs of oil deterioration, or abnormal wear to verify the need to change oil.
- Be aware that both of these test methods have variability of approximately ± 1 TBN. Care should be taken when analyzing the results of the TBN test. Consult a trained S·O·S Services analyst when making oil drain decisions based on oil sample results.

Note: The use of Cat S·O·S Services oil analysis helps environmental sustainability as the best way to optimize oil life. The service will help engines reach the expected life. Consult your Cat dealer regarding the testing required to establish a safe, optimized oil drain interval.

In order to help protect your engine, and optimize oil drain intervals for engine applications and duty cycles, use Cat S·O·S Services oil analysis as follows:

- Recommended as a matter of course
- Recommended in order to determine oil drain intervals when operating on fuel with sulfur levels between 0.05% (500 ppm) and 0.5% (5000 ppm)
- Required in order to determine oil drain intervals when operating on fuel with sulfur levels that are above 0.5% (5000 ppm)

Excessive piston deposits can be produced by oil with a high TBN and/or high ash. These deposits can lead to a loss of control of the oil consumption and to the polishing of the cylinder bore.

There are many factors that contribute to rapid TBN depletion, a not all inclusive list follows:

- High sulfur fuel (The more fuel sulfur, the more rapid the TBN depletion.)
- Faulty engine coolant regulators
- Light loads
- Short operation cycles
- Excessive idling
- Operating in applications where normal operating temperature is seldom reached

- High humidity (allowing excessive condensation)

Bullets 2 through 7 directly above all can contribute to excessive water in the crankcase oil. The water combines with available sulfur to form sulfuric acid. Neutralizing acids that are formed contribute to rapid TBN depletion.

Depending on application severity and localized environmental conditions, and also depending on maintenance practices, operating Direct Injection (DI) diesel engines and operating PC (Precombustion Chamber) diesel engines on fuel with sulfur levels over 0.1 percent (1000 ppm) may require shortened oil change intervals in order to help maintain adequate wear protection. Refer to this Special Publication, "Fuel Specifications" section, "Diesel Fuel Sulfur" topic for additional information.

Note: Do NOT use only this special publication as a basis for determining oil drain intervals.

This Special Publication does not address recommended oil drain intervals, but rather provides guidance that should be used with your specific Operation and Maintenance Manual in determining acceptable oil drain intervals. Refer to the Operation and Maintenance Manual, and consult your Cat dealer to determine the acceptable oil drain interval.

Note: Engine operating conditions play a key role in determining the effect that fuel sulfur will have on engine deposits and on engine wear. Consult your Cat dealer for guidance when fuel sulfur levels are above 0.1% (1000 ppm).

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Engine Oil for Precombustion Chamber (PC) Diesel Engines (Engine Crankcase Fluid Recommendations for All 3500 Series and Smaller PC Diesel Engines)

SMCS Code: 1348; 7581

Most Cat medium and heavy-duty PC diesel engines were produced before 1991.

Cat Precombustion Chamber Oil (Cat PCO) is acceptable for use in Cat PC diesel engines. Cat PCO is available in SAE 40 grade. In addition, PC diesel engines can use the multigrade oils that are recommended for DI diesel engines.

For lubricant information, refer to the "Lubricant" section of this Special Publication for engine oils.

NOTICE

Do not use single grade API CF oils or multigrade API CF oils in Cat 3500 Series, C175 Series and smaller Direct Injection (DI) diesel engines.

API CF oils are only recommended for Cat 3600 Series and C280 Series diesel engines, and Cat engines that have precombustion chamber (PC) fuel systems. Oils that are used in Cat 3600 Series and C280 Series diesel engines must also pass a 7000 hour field performance evaluation. Contact your Cat dealer for details.

Total Base Number (TBN) and Fuel Sulfur Levels for Precombustion Chamber (PC) Diesel Engines

The use of Cat S·O·S Services oil analysis is strongly recommended for determining oil life.

Note: The following information concerning oil life relative to used oil TBN level is provided for general information only, and is not the recommended method for determining oil life. **If the one half of new oil TBN guideline that is stated below is used for determining oil life it must only be used in conjunction with a complete S·O·S Services oil analysis program.**

Note: TBN is also commonly referred to as Base Number (BN).

Note: Oils that have not met the requirements of at least one Cat ECF specification may cause reduced engine life.

Note: While API CF category single grade and multigrade oils may be acceptable for use in PC diesel engines, API CF oils and single grade oils are not acceptable for use in Cat DI engines. Excessive piston deposits will occur when oils that meet only the API CF oil category are used in Cat 3500 Series, C175 Series and smaller DI diesel engines.

The minimum required Total Base Number (TBN) for oil depends on the fuel sulfur level. For PC diesel engines that use distillate fuel, the minimum new oil TBN must be 20 times the fuel sulfur level.

Note: The typical units used to express sulfur concentration are: parts per million (ppm), mg/kg or percent. The two units ppm and mg/kg are equivalent. In order to convert fuel sulfur level from ppm or mg/kg to percent, divide the ppm or mg/kg value by 10,000.

- Fuel of sulfur level 500 ppm is 0.05 percent sulfur ($500 / 10,000 = 0.05$)

- Fuel of sulfur level 1000 ppm is 0.1 percent sulfur ($1000 / 10,000 = 0.1$)

Note: The minimum TBN of the new oil is 7 regardless of the fuel sulfur level.

TBN testing is an optional part of the SOS Services oil analysis program. TBN testing may be done in addition to the standard SOS Services tests for oil deterioration. In most applications, the SOS Services tests for oxidation, sulfation, viscosity, and wear will identify oil deterioration.

TBN of the oil is typically measured using "ASTM D2896" and/or "ASTM D4739" test methods. Both methods can be used to measure the TBN of used oils. However, "ASTM D4739" is the preferred method for used oils.

- Consider changing the oil if the "ASTM D2896" test result reaches 4 TBN. Look for other signs of oil deterioration, or abnormal wear to verify the need to change oil.
- Consider changing the oil if the "ASTM D4739" test result reaches 3 TBN. Look for other signs of oil deterioration, or abnormal wear to verify the need to change oil.
- Be aware that both of these test methods have variability of approximately ± 1 TBN. Care should be taken when analyzing the results of the TBN test. Consult a trained S·O·S Services analyst when making oil drain decisions based on oil sample results.

Note: The use of Cat S·O·S Services oil analysis helps environmental sustainability as the best way to optimize oil life. The service will help engines reach the expected life. Consult your Cat dealer regarding the testing required to establish a safe, optimized oil drain interval.

In order to help protect your engine, and optimize oil drain intervals for engine applications and duty cycles, use Cat S·O·S Services oil analysis as follows:

- Recommended as a matter of course
- Recommended in order to determine oil drain intervals when operating on fuel with sulfur levels between 0.05% (500 ppm) and 0.5% (5000 ppm)
- Required in order to determine oil drain intervals when operating on fuel with sulfur levels that are above 0.5% (5000 ppm)

Excessive piston deposits can be produced by oil with a high TBN and/or high ash. These deposits can lead to a loss of control of the oil consumption and to the polishing of the cylinder bore.

NOTICE

Depending on application severity and localized environmental conditions, and also depending on maintenance practices, operating Direct Injection (DI) diesel engines and operating PC (Precombustion Chamber) diesel engines on fuel with sulfur levels over 0.1 percent (1000 ppm) may require significantly shortened oil change intervals in order to help maintain adequate wear protection. Refer to this Special Publication, "Fuel Specifications" section, "Diesel Fuel Sulfur" topic for additional information.

Note: For PC (Precombustion Chamber) diesel engines, which are mainly 1990 and older engines, the minimum new oil TBN must be 20 times the fuel sulfur level. The diesel engine oil types, specifications, and viscosity grades recommendations provided for DI diesel engines in this Special Publication are also applicable to PC diesel engines.

Consult with your Cat dealer regarding the testing that is required in establishing oil drain intervals that are optimized for your application.

In order to help protect your engine, and in order to help optimize oil drain intervals for engine specific applications and duty cycles, Cat S-O-S Services oil analysis is:

- Recommended as a matter of course
- Very strongly recommended in order to determine oil drain intervals when operating on fuel with sulfur levels between 0.05% (500 ppm) and 0.5% (5000 ppm)
- Required in order to determine oil drain intervals when operating on fuel with sulfur levels that are above 0.5% (5000 ppm)

Note: Engine operating conditions play a key role in determining the effect that fuel sulfur will have on engine deposits and on engine wear. Consult your Cat dealer for guidance when fuel sulfur levels are above 0.1% (1000 ppm).

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Marine Transmission Oil

SMCS Code: 3080; 3300; 7581

Cat Transmission/Drive Train Oils

Cat TDTO (Transmission/Drive Train Oil) is balanced in order to give maximum frictional material service life and performance in Cat transmissions. Cat TDTO exceeds the requirements for the Cat TO-4 oil specification which includes the frictional requirements and gear wear requirements. Cat TDTO is offered in different lubricant viscosity grades for maximum service life of components at high ambient temperatures and heavy-duty cycles.

For optimum transmission service life and performance, Cat TDTO is recommended.

Table 5

Lubricant Viscosities for Ambient Temperatures for Cat Marine Transmissions						
Cooling of transmission	Oil Type and Performance Requirements	Viscosity Grade	°C		°F	
			Min	Max	Min	Max
Raw/Sea Water	Cat TDTO Cat TO-4	SAE 30	-15	80	5	176
		SAE 50	-5	95	23	203
Jacket Water		SAE 50	-5	95	23	203

Consult your Cat dealer for part numbers and for sizes of available containers.

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Cat TDTO oil is formulated for transmissions and drive trains only, and should not be used in engines. Shortened engine life will result.

NOTICE

Cat GO is not the same as Cat TDTO, and does not meet Cat TO-4 or TO-4M oil Performance Requirements. Cat GO or commercial gear oils should not be used in compartments that specify Cat TO-4 or TO-4M oil.

Commercial Transmission Oils

If Cat TDTO (Transmission/Drive Train Oil) is not used, commercial oils meeting the Cat TO-4 specification must be used in Cat marine transmissions. Use TO-4 specification oils that are single grade only.

Commercial Marine Transmissions

For marine transmissions which are not manufactured by Cat, refer to the lubrication recommendation of the Original Equipment Manufacturer (OEM).

Lubricant Viscosities

SMCS Code: 1000; 7000; 7581

Selecting the Viscosity

Ambient temperature is the temperature of the air in the immediate vicinity of the machine. This temperature may differ due to the machine application from the generic ambient temperature for a geographic region. When selecting the proper oil viscosity for use, review both the regional ambient temperature and the potential ambient temperature for a given machine application. Generally, use the higher temperature as the criterion for the selection of the oil viscosity. Generally, use the highest oil viscosity that is allowed for the ambient temperature when you start the machine. Refer to the "Lubricant Viscosities for Ambient Temperatures" tables for guidance. In cold weather applications, the preferred method is to use properly sized machine compartment heaters and a higher viscosity grade oil. Thermostatically controlled heaters that circulate the oil are preferred.

The proper oil viscosity grade is determined by the minimum ambient temperature (the air in the immediate vicinity of the machine). In order to determine the proper oil viscosity grade, refer to the "Min" column in the table. This information reflects the coldest ambient temperature condition for starting a cold machine and for operating a cold machine. Refer to the "Max" column in the table in order to select the oil viscosity grade for operating the machine at the highest temperature that is anticipated. Unless specified otherwise in the tables, use the highest oil viscosity that is allowed for the ambient temperature when you start the machine.

Engines that are operated continuously should use oils that have the higher oil viscosity in the final drives and in the differentials. The oils that have the higher oil viscosity will maintain the highest possible oil film thickness. Refer to this Special Publication, "General Information for Lubricants" article, Lubricant Viscosities tables, and any associated footnotes. Consult your Cat dealer if additional information is needed.

Note: SAE 0W and SAE 5W oils, are not recommended for use in engines that are operated continuously and/or are heavily loaded. Refer to the "Lubricant Viscosities for Ambient Temperatures" tables for guidance. The oils that have the higher oil viscosity will maintain the highest possible oil film thickness. Consult your Cat dealer if additional information is needed.

Note: Generally, use the highest oil viscosity that is available to meet the requirement for the temperature at start-up.

Proper oil viscosity AND oil type/specification are required to maximize engine performance and life. Do NOT use only oil viscosity, or only oil type to determine the engine oil selection. Using only the oil viscosity or only the oil type to determine the engine oil selection can lead to reduced performance and engine failure. Refer to the "Lubricant Viscosities for Ambient Temperatures" tables and to ALL of the associated footnotes.

Follow the recommendations found in the "Lubricant Viscosities for Ambient Temperatures" tables and associated footnotes in order to enhance performance and reduce risk of engine failure.

In colder ambient conditions an engine warm-up procedure and/or supplemental engine fluid compartment heat may be required. Engine warm-up procedures can typically be found in the Operation and Maintenance Manual for the engine. The "Lubricant Viscosities for Ambient Temperatures" tables in this Special Publication include footnotes that address engine warm-up.

Note: Different brand oils may use different additive packages to meet the various engine performance category/specification requirements. For the best results, do not mix oil brands.

Note: The availability of the various Cat oils will vary by region.

Lubricant Viscosity Recommendations for Direct Injection (DI) and Precombustion Chamber (PC) engines

Refer to the minimum temperature in table 6 in order to determine the required oil viscosity for starting a cold engine. Refer to the maximum temperature in order to select the oil viscosity for engine operation at the highest ambient temperature that is anticipated.

Refer to this Special Publication, "General Information for Lubricants" article for important lubricant information.

Supplemental heat is recommended for cold-soaked starts below the minimum ambient temperature. Supplemental heat may be required for cold-soaked starts that are above the minimum temperature that is stated, depending on the parasitic load and other factors. Cold-soaked starts occur when the engine has not been operated for a time, allowing the oil to become more viscous in cooler ambient temperatures.

For oil recommendations for Tier 4 EPA certified engines, EU stage IIIB and IV type approved engines, and Japan Step IV approved engines refer to the Special Publication, "Engine Oil" section. Refer to this Special Publication, "Lubricant Information" section for a list of all Cat engine oils.

Note: Use the highest oil viscosity that is available to meet the requirement for the temperature at start-up.

If ambient temperature conditions at engine start-up require the use of multigrade SAE 0W oil, SAE 0W-40 viscosity grade is preferred over SAE 0W-30.SAE.

Note: 10W-30 is the preferred viscosity grade for the following diesel engines when the ambient temperature is above -18°C (0°F) and below 40°C (104°F).

- C7
- C.9
- C9
- 3116
- 3126

Note: C175 Series diesel engines require the use of multigrade SAE 40 oil: SAE 0W-40, SAE 5W-40, SAE 10W-40, or SAE 15W-40. In ambient temperatures of -9.5°C (15°F) or above, SAE 15W-40 is the preferred oil viscosity grade. Refer to table 6 and associated footnotes for guidance on selecting the proper oil viscosity grade for various ambient temperatures.

Table 6

Lubricant Viscosities for Ambient Temperatures for Cat Diesel Engines						
Engine Type	Oil Type and Performance Requirements	Viscosity Grade	°C		°F	
			Min	Max	Min	Max
Direct Injection (DI) and Pre Combustion (PC)	Cat Cold Weather DEO-ULS	SAE 0W-40	-40	40	-40	104
	Cat DEO-ULS SYN	SAE 5W-40	-30	50	-22	122
	Cat DEO-ULS Cat DEO	SAE 10W-30	-18	40	0	104
		SAE 15W-40	-10	50	14	122
	Cat ECF-1-a, Cat ECF-2, Cat ECF-3	SAE 0W-30	-40	30	-40	86
		SAE 5W-30	-30	30	-22	86
		SAE 10W-40	-18	50	0	122
Pre Combustion (PC) only	Cat SAE0 API CF or equivalent	SAE 30	0	40	32	104
		SAE 40	5	50	41	122

Commercial multi-grade oil alternatives must claim at least one of the following Cat specifications: Cat ECF-1-a, Cat ECF-2, Cat ECF-3. Non-Cat commercial oils are as a group second choice oils.

Refer to this Special Publication, "Lubricant Viscosities" and "Cold Weather Lubricants" for additional information.

Lubricant Viscosity Recommendations (3116 and 3126 Marine Engines)

The information provided in the "Lubricant Viscosities, Selecting the Viscosity" article in the "DI and PC Engines" section is applicable to 3116 and 3126 Marine Engines.

The proper SAE viscosity grade of oil is determined by the minimum ambient temperature during cold engine start-up. The proper viscosity is also determined by the maximum ambient temperature during engine operation.

Refer to Table 7, minimum temperature, in order to determine the required oil viscosity for starting a cold engine. Refer to maximum temperature in order to select the oil viscosity for engine operation at the highest ambient temperature that is anticipated.

Refer to the "General Information for Lubricants" article for important lubricant information.

Supplemental heat is recommended for cold-soaked starts below the minimum ambient temperature. Supplemental heat may be required for cold-soaked starts that are above the minimum temperature. Use of supplemental heat may depend on the parasitic load and other factors. Cold-soaked starts occur when the engine has not been operated for a time, allowing the oil to become more viscous in cooler ambient temperatures.

Use the highest oil viscosity that is allowed for the ambient temperature at start-up.

Table 7

Lubricant Viscosities for Ambient Temperatures for Cat 3116 and 3126 Marine Engines						
Engine Model	Oil Type and Performance Requirements	Viscosity Grade	°C		°F	
			Min	Max	Min	Max
3116 and 3126 Marine Diesel Engines	Cat SAEO API CF or equivalent	SAE 30	0	40	32	104
		SAE 40	5	50	41	122

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Synthetic Basestock Oils

SMCS Code: 1300; 1348; 7581

Synthetic base oils are acceptable for use in Cat engines. **These oils must meet the performance requirements that are specified by Cat for the engine compartment.**

Synthetic base oils generally perform better than conventional oils in the following two areas:

- Synthetic base oils have improved flow at low temperatures, especially in arctic conditions.
- Synthetic base oils have improved oxidation stability, especially at high operating temperatures.

Some synthetic base oils have performance characteristics that enhance the service life of the oil. However, Cat does not recommend the automatic extension of oil drain intervals for any type of oil, whether synthetic or non-synthetic.

Oil drain intervals for Cat engines can only be adjusted higher (longer interval) after an oil analysis program that contains the following data:

- Oil condition, oil contamination, and wear metal analysis (Cat S·O·S Services oil analysis)
- Trend analysis
- Fuel consumption
- Oil consumption

Refer to the "Extended Engine Oil Drains and Warranty" article in the Foreword of this Special Publication.

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Re-refined Basestock Oils

SMCS Code: 1300; 1348; 7581

Rerefined basestock oils are acceptable for use in Cat engines **IF these oils meet the performance requirements that are specified by Cat.**

Rerefined basestock oils can be used exclusively in finished oil or in a combination with new basestock oils. The US military specifications and the specifications of other heavy equipment manufacturers also allow the use of rerefined basestock oils that meet the same criteria.

The process that is used to make rerefined basestock oil should adequately remove all wear metals and all additives that are in the used oil. Vacuum distillation and the hydrotreating of the used oil are acceptable processes that are used for producing rerefined base oil.

Note: Filtering is inadequate for the production of high quality rerefined basestock oils from used oil.

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Aftermarket Oil Additives

SMCS Code: 1300; 1348; 7581

Cat does not recommend the use of aftermarket additives in oil. Aftermarket additives are not necessary in order to achieve the maximum service life of the engine or rated performance of the engine. Fully formulated, finished oils consist of base oils and of commercial additive packages. These additive packages are blended into the base oils at precise percentages in order to help provide performance characteristics that meet industry standards.

There are no industry standard tests that evaluate the performance or the compatibility of aftermarket additives in finished oil. Aftermarket additives may not be compatible with the finished oil additive package, which could lower the performance of the finished oil. The aftermarket additive could fail to mix with the finished oil and produce sludge in the crankcase. Cat discourages the use of aftermarket additives in finished oils.

To achieve the best performance from a Cat engine, conform to the following guidelines:

- Select the proper Cat oil or commercial oil that has passed the Field Performance Evaluation. Refer to the "Selecting a Commercial Oil" article in the "Lubricant Specifications" section of this Special Publication.
- Refer to the appropriate "Lubricant Viscosities for Ambient Temperatures" table in this Special Publication in order to find the correct oil viscosity grade for your engine.
- At the specified interval, service the engine compartment. Use appropriate new oil and install an appropriate new oil filter.
- Perform maintenance at the intervals that are specified in the Operation and Maintenance Manual, "Maintenance Interval Schedule".

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Specialty Lubricants

SMCS Code: 7000; 7581

Table 8

Special-Purpose Cat Lubricants	
Item	Size
6V-4876 Lubricant ⁽¹⁾	500 g (17.6 oz)
5P-3931 Thread Compound ⁽²⁾	150 g (5.3 oz)

⁽¹⁾ Recommended for use on typical components such as head bolt threads and washers.

⁽²⁾ Recommended for mating connectors such as exhaust manifold studs and exhaust manifold nuts.

Table 9

UV Visible Dyes for Leak Detection			
Part Number	Description	Size	Dosage
To detect oil leaks in engines, transmissions, hydraulic systems			
1U-5572	Oil Glo 22 Additive	28.4 gram (1 ounce) bottle	28.4 gram (1 ounce) per 7.58 L (2 US gal) of oil
1U-5573	Oil Glo 22 Additive	0.47 L (1 pint) bottle	28.4 gram (1 ounce) per 7.58 L (2 US gal) of oil
To detect fuel leaks or suspected fuel dilution			
1U-5574	Gas Glo 32 Additive	28.4 gram (1 ounce) bottle	28.4 gram (1 ounce) per 37.9 L (10 US gal) of gasoline or diesel fuel
1U-5575	Gas Glo 32 Additive	0.47 L (1 pint) bottle	28.4 gram (1 ounce) per 37.9 L (10 US gal) of gasoline or diesel fuel
To detect cooling system leaks			
1U-5576	Water Glo 23 Additive	28.4 gram (1 ounce) bottle	28.4 gram (1 ounce) per 151.5 L (40 US gal) of water
1U-5577	Water Glo 23 Additive	0.47 L (1 pint) bottle	28.4 gram (1 ounce) per 151.5 L (40 US gal) of water

The dyes must be used with a special Glo Gun to detect the leaks. Consult with your local Cat dealer for availability.

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Cold Weather Lubricants

SMCS Code: 1300; 1348; 7581

NOTICE

Recommended engine warm-up procedure must be followed. Refer to the engine Operation and Maintenance Manual. Also refer to the relevant "Lubricant Viscosities for Ambient Temperatures" table footnote in this Special Publication.

NOTICE

Excessive engine idling time can contribute to excessive water in the crankcase oil, causing corrosion, sludge, and other problems. Excessive engine idling time can also lead to injector fouling, piston and combustion chamber deposits, corrosive damage, and increased oil consumption.

For proper selection of oil viscosity grade and oil type and/or specification, refer to this Special Publication, "Lubricant Specifications" section.

Also, refer to this Special Publication, "Lubricant Viscosities" article.

NOTICE

Not following the recommendations found in the "Lubricant Viscosities for Ambient Temperatures" table and associated footnotes can lead to reduced performance and engine failure.

NOTICE

Do NOT use only the oil viscosities when determining the recommended oil for an engine compartment. The oil type (performance requirements) MUST also be used.

For easier cold weather starting, make sure that all of the components of the engine electrical system are properly maintained. All electrical wiring and connections should be free of the following: fraying, damaged insulation, and corrosion. Batteries should be kept fully charged and warm. The batteries and the battery cables must be sized properly for the application.

Various starting aids are available in order to assist with cold engine starts in low temperature conditions. Follow the recommendations that are provided by the manufacturer of the starting aid. Refer to the foreword section of this Special Publication, "Aftermarket Products and Warranty".

For additional information concerning cold-weather operation, refer to this Special Publication, "Fuel Specifications" section. Also refer to this Special Publication, "Cooling System Specifications" section.

Before attempting to start the engine, make sure that the oil in the engine is fluid enough to flow. Check the oil by removing the dipstick. If the oil will drip from the dipstick, then the oil should be fluid enough to allow the engine to start. Do not use oil that has been diluted with kerosene. Kerosene will evaporate in the engine, and cause the oil to thicken. Kerosene will cause swelling and softening of the silicone seals. Kerosene will dilute the oil additives. Dilution of the oil additives will reduce the performance, and reduce the engine protection that the additives provide.

If the viscosity of the oil is changed for colder weather, also change the filter element. If the filter is not changed, the filter element and the filter housing can become a solid mass. After you change the oil, operate the engine in order to circulate the thinner oil.

When you start a cold-soaked engine or when you operate an engine in ambient temperatures that are below -18°C (0°F), use base oils that can flow in low temperatures. These multigrade oils have lubricant viscosity grade of SAE 0W or of SAE 5W. An example of viscosity grade is SAE 5W-40.

When you start a cold-soaked engine or when you operate an engine in ambient temperatures that are below -30°C (-22°F), use synthetic basestock multigrade oil. The oil should have a lubricant viscosity grade of SAE 0W or SAE 5W. Use oil with a pour point that is lower than -40°C (-40°F).

Note: Use the highest oil viscosity grade that is allowed for the ambient temperature when you start the engine. If a different oil viscosity grade is specified in the table, use the viscosity grade that is specified in the table. **In arctic applications, the preferred method of lubrication is to use a properly sized engine compartment heater and a higher viscosity grade oil.** Refer to the "Lubricant Viscosities" article in this Special Publication for further details.

Note: Cold-soaked starts occur when the engine has not been operated for a time. The oil will become more viscous due to cooler ambient temperatures. Supplemental heat is recommended for cold-soaked starts that are below the minimum ambient temperatures listed in the "Lubricant Viscosities for Ambient Temperatures" tables. Supplemental heat may be required for cold-soaked starts that are above the minimum temperature that is stated, depending on the parasitic load and other factors.

NOTICE

Engines that use fluid or pan heaters, or heated enclosures, or are kept running under load, etc. can, and generally should use higher viscosity oil. The "Lubricant Viscosities for Ambient Temperatures" tables (Maintenance Section) **Minimum** viscosity for ambient temperature recommendations are for cold-soaked conditions. Use the highest viscosity oil that is allowed for the ambient temperature at startup. **BUT, under continuous usage (multiple shifts per day), and/or when using fluid or pan heaters, use a higher viscosity oil than the minimum recommended viscosity for cold-soaked starting conditions.** The higher viscosity oil will maintain the highest possible oil film thickness. Refer to the "Lubricant Viscosities for Ambient Temperatures" tables and the table footnotes for exceptions.

Example: The oil viscosity recommended for use in Cat diesel engines for cold-soaked starts at -40°C (-40°F) is multigrade oil of the SAE 0W viscosity grade (SAE 0W-30). If the diesel engine is run continuously, SAE 15W-40 viscosity grade diesel engine oil can be used and is generally the preferred oil viscosity in this situation.

NOTICE

If ambient conditions warrant, a higher viscosity oil of the recommended specification for a given compartment may need to be installed in order to provide adequate film thickness.

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S·O·S Services Oil Analysis

SMCS Code: 1000; 1348; 3080; 4070; 4250; 4300; 5095; 7000; 7542; 7581

NOTICE

These recommendations are subject to change without notice. Consult your local Cat dealer for the most up to date recommendations.

Cat has developed a maintenance management tool that evaluates oil degradation and detects the early signs of wear on internal components. The Cat tool for oil analysis is called S·O·S oil analysis and the tool is part of the S·O·S Services program. S·O·S oil analysis divides oil analysis into four categories:

- Component wear rate
- Oil condition
- Oil contamination
- Oil identification

Component Wear Rate analysis evaluates the wear that is taking place inside the lubricated compartment. The S·O·S Services analyst uses the results of elemental analysis and particle count tests to evaluate the wear. Trend analysis and proprietary wear tables are then used to determine if wear rates are normal or abnormal.

Oil Condition analysis is used to determine if the oil has degraded. Tests are done to look at the oxidation, sulfation, and viscosity of the oil. The S·O·S Services analyst uses established guidelines or trend analysis to determine if the oil has reached the useful life limit.

Oil Contamination tests are performed to determine if anything harmful has entered the oil. This analysis relies on the results from the following tests: elemental analysis, soot, particle count, fuel dilution, water, and glycol. The S·O·S Services program has guidelines for the level of contamination that are allowed in Cat engines.

Oil Identification is another important part of the S·O·S oil analysis program. The wrong oil in an engine can severely damage major components. The S·O·S Services analyst uses elemental analysis and viscosity results to identify key characteristics of the oils.

These four types of analysis are used to monitor the condition of your equipment, and to help you identify potential problems. A properly administered S·O·S Services oil analysis program will reduce repair costs and the program will lessen the impact of downtime.

The S·O·S oil analysis program uses a wide range of tests to determine the condition of the oil and the lubricated compartment.

Guidelines that are based on experience and a correlation to failures have been established for these tests. See the following chart for the guidelines. Exceeding one or more of these guidelines could indicate serious fluid degradation or a pending component failure. A trained person at your Cat dealership should make the final analysis.

Oil analysis is one of the diagnostic tools to determine engine health. Oils that are within the limits given by the guidelines may not indicate all engine health issues. Under certain conditions, including but not limited to severe operating conditions, oils that are within the limits given by the guidelines may require changing early.

Note: Cooling system problems will also reduce the life of engines. S·O·S coolant analysis and S·O·S oil analysis provide a complete and accurate method for monitoring the health of all engine systems. Refer to the S·O·S Services coolant analysis information in this Special Publication. A properly administered S·O·S Services program will reduce repair costs and lessen the impact of downtime.

Refer to the "Contamination Control" article in this Special Publication for recommended fluid cleanliness targets.

Table 10

S·O·S Oil Analysis Guidelines	
Test Parameter	Guideline
Oxidation	(1)
Soot	(1)
Sulfation	(1)
Wear Metals	Trend Analysis and Cat Wear Table ⁽¹⁾ norms
Water	0.5% maximum
Glycol	0%
Fuel Dilution	based on viscosity ⁽¹⁾ and GC ⁽²⁾ fuel dilution in excess of 4%
Viscosity "ASTM D445" measured at 100° C (212° F)	+/-3 centistoke (cSt) change from new oil viscosity.

(1) Acceptable values for these parameters are proprietary to the S·O·S oil analysis program.

(2) Gas Chromatograph

Note: Most oil analysis programs do not detect larger particles in the oil sample. Some failure modes only produce larger particles. Oil analysis alone will not always detect an impending failure. Oil filters should be sectioned and inspected for the presence of visible particles.

The engine oil consumption must be measured and recorded. A significant increase in oil consumption can indicate a problem with cylinder pack deposits or components. Additionally, oil additions dilute wear metals and other contaminants. Oil analysis results may become inaccurate.

Consult your Cat dealer for complete information and assistance about the S·O·S oil analysis program.

Obtaining S·O·S Oil Samples

Before you obtain an S·O·S oil sample, operate the engine until the oil is warm and the oil is circulated. Then obtain the S·O·S oil sample.

In order to obtain a good oil sample, do not take the oil sample from the drain stream. The drain stream method can allow a stream of dirty oil from the bottom of the compartment to contaminate the sample. Likewise, never dip an oil sample from an oil container or pour a sample from a used filter.

There are two acceptable ways to obtain S-O-S oil samples. **The following methods are listed in the order that is preferred:**

- Use an in-line sampling valve on the pressurized oil manifold.
- Use a sampling gun (vacuum pump) that is inserted into the sump.

Use of the in-line sampling valve is the preferred method. This method provides samples that are less likely to be contaminated. Whenever you obtain the samples, obtain the samples from the same point. The samples will be more representative of the oil that is in the system.

Normally, the oil sample is taken at low idle. If the flow rate is too low, increase engine speed to high idle in order to obtain the oil sample.

NOTICE

Do not use the same vacuum sampling pump for extracting oil samples that is used for extracting coolant samples.

A small residue of either type sample may remain in the pump and may cause a false positive analysis for the sample being taken.

Always use a separate pump for oil sampling and a separate pump for coolant sampling.

Failure to do so may cause a false analysis which could lead to customer and dealer concerns.

Oil Sampling Interval

Take the oil samples as close as possible to the standard intervals. In order to receive the full value from S-O-S oil analysis, establish a consistent trend of data. In order to establish a pertinent history of data, perform consistent oil samplings that are evenly spaced.

Recommended interval for engine oil samples is given in Table 11. A 250 hour sampling interval can provide a timely indication of oil contamination and oil degradation.

Measure and record engine oil consumption in order to allow accurate oil analysis. Oil additions during the sampling interval dilute wear metals and other contaminants.

Table 11

S-O-S Oil Sampling Interval for Engine crankcase	
Recommended Interval ⁽¹⁾⁽²⁾	Oil Type
Every 250 Service Hours	Cat DEO Cat DEO-ULS

(1) Severe applications may require a more frequent oil sampling interval.

(2) Under certain conditions, the Cat dealer or the Operation and Maintenance Manual may allow a longer interval between oil samplings.

Note: Refer to the Operation and Maintenance Manual for your engine for recommended oil drain intervals.

Consult your Cat dealer for complete information and assistance in order to establish an S-O-S Services program for your engine.

More Frequent S-O-S Sampling Improves Life Cycle Management

Traditionally, the suggested S-O-S sampling intervals for diesel engines have been at 250 hours. However in severe applications, more frequent oil sampling is recommended. Severe service for lubricated compartments occurs at high loads, in high temperatures, and in dusty conditions. If any of these conditions or other severe service indicators exist, sample the engine oil at 125 hour intervals. These additional samples will increase the chance of detecting a potential failure.

Determining Optimum Oil Change Intervals

Sampling the engine oil at every 125 hours provides information for oil condition and for oil performance. This information is used to determine the optimum usable life of a particular oil. Also, more points of data will allow closer monitoring of component wear rates. Close monitoring also allows you to obtain the maximum use of the oil. For detailed information on optimizing oil change intervals, consult your Cat dealer.

This Special Publication does not address recommended oil drain intervals. Refer to your engine Operation and Maintenance Manual, and consult your Cat dealer for additional guidance, including but not limited to guidance on establishing optimized and/or acceptable oil drain intervals.

Note: The use of Cat S·O·S Services oil analysis helps environmental sustainability as the best way to optimize oil life. S·O·S Services will help engines reach expected life. Consult your Cat dealer regarding the testing required to establish a safe, optimized oil drain interval.

Standard oil drain intervals as published in engine Operation and Maintenance Manual are for typical applications:

- Using recommended oils
- Using good fuel
- Using recommended filters
- Using industry standard good maintenance practices
- Following maintenance intervals as published in engine Operation and Maintenance Manual

More severe applications may require shortened oil drain intervals, while less severe applications may allow for longer than standard oil drain intervals. High load factors (above 75%), particularly with high sulfur fuels, can contribute significantly to reducing oil drain intervals below standard oil drain intervals.

Consult your Cat dealer regarding the testing that is required in establishing oil drain intervals that are optimized for your application.

In order to help protect your engine, and help optimize oil drain intervals for engine applications and duty cycles, use Cat S·O·S Services oil analysis as follows:

- Recommended as a standard practice
- Recommended in order to determine oil drain intervals when using fuel with sulfur levels between 0.05% (500 ppm) and 0.5% (5000 ppm)
- Required in order to determine oil drain intervals when using fuel with sulfur levels that are above 0.5% (5000 ppm)

Note: Engine operating conditions play a key role in determining the effect that fuel sulfur will have on engine deposits and on engine wear. Consult your Cat dealer for guidance when fuel sulfur levels are above 0.1% (1000 ppm).

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Lubricating Grease

SMCS Code: 0645; 1000; 7000; 7581

NOTICE

These recommendations are subject to change without notice. Consult your local Cat dealer for the most up to date recommendations.

Note: Non-Cat commercial greases are as a group second choice greases. Within this grouping of second choice greases there are tiered levels of performance.

NOTICE

Cat does not warrant the quality or performance of non-Cat fluids and greases.

Cat provides various greases that vary in performance from a moderate performance to high performance. These greases are used in the entire line of Cat products in the wide variety of climates throughout the world. From this variety of Cat grease products, you can find a Cat grease that will meet or exceed the performance required.

Before selecting a grease product, the performance requirements must be determined. Consult the grease recommendations in your Operation and Maintenance Manual. Also, consult your Cat dealer for a list of greases that have the performance specifications and the available container sizes.

Note: Always choose grease that meets or exceeds the recommendations that are specified by the equipment manufacturer for the application.

Some work sites require the use of a single grease to fulfill the needs of all the equipment. Always choose a grease that meets or exceeds the requirements of the most demanding application. Remember that the products which barely meet the minimum performance requirements can be expected to produce the minimum parts life. False economy is being used if a grease is purchased with the lowest cost as the only consideration. Instead, use the grease that yields the lowest total operating cost. This cost should be based on an analysis of the costs of parts, labor, downtime, and the amount of grease that is required.

Note: Certain Cat grease products are formulated with Molybdenum disulfide (MoS₂ or "Moly"). The Moly used in Cat greases is of a special ultra fine technical grade. The maximum particle size of the Moly used in Cat greases is 5 microns. The typical median size of the Moly is 3 microns. This size meets the special requirements of some rolling element bearings, joints, and other moving components of tight clearances.

Note: When the grease in a joint is changed from one type of grease to another or a grease from a different supplier is to be used, Cat recommends purging all of the old grease from the joint. Some greases are not chemically compatible. Consult your supplier in order to determine if the greases are compatible.

If in doubt, Purge!

Note: All Cat greases are "chemically" compatible with each other. Mixing of Cat greases will not result in an adverse chemical reaction. However, mixing of Cat greases might result in reduced performance.

Moderate Applications

Cat greases that are developed for moderate applications are made with a lithium complex thickener. This type of grease is applicable for moderate applications of medium loads and speeds. These greases are formulated to provide optimal performance for these applications.

Cat Multipurpose Grease

Cat Multipurpose Grease is a National Lubricating Grease Institute (NLGI) grade 2 grease. This grease is made with petroleum base oil and a lithium complex thickener. Cat Multipurpose Grease is formulated for use in applications that have a low severity to a medium severity and moderate temperatures.

Cat Multipurpose Grease meets the NLGI certification of "GC-LB".

Note: If the application calls for a multipurpose grease and Cat Multipurpose Grease is not available, consult the grease data sheets. Use an alternative grease that meets or exceeds the performance characteristics of Cat Multipurpose Grease.

Cat White Assembly Grease

Cat White Assembly Grease is an NLGI grade 2 grease. This grease is made with a petroleum base oil and a lithium complex thickener. Cat White Assembly Grease is formulated for use in applications that have low to medium severity and moderate temperatures. This grease has been made extra tacky in order to hold gaskets, O-rings, and needle bearings to aid in the assembly of engines, transmissions, and other components.

Note: Cat White Assembly Grease or any other grease product should not be used when installing rod bearing and main bearings. Any grease product can hold debris and cause bearing damage. Only clean oils should be used when installing rod bearings and main bearings.

Cat High Speed Ball Bearing Grease

Cat High Speed Ball Bearing Grease is an NLGI grade 2 grease. This grease is made with a petroleum base oil and a polyurea thickener. This grease is recommended for applications that utilize roller bearings and ball bearings at low loads to moderate loads at high speed. Typical applications for this grease are electric motors, alternators, and constant velocity (CV) joints for automotive products.

Cat High Speed Ball Bearing Grease is formulated not to contain lead, antimony, barium, zinc, phosphorous, or chlorine additives. Therefore, Cat High Speed Ball Bearing Grease has a lower impact on the environment than many other types of grease.

Cat Multipurpose Marine Grease

Cat Multipurpose Grease is a National Lubricating Grease Institute (NLGI) grade 2 grease. This grease is made with petroleum base oil and a calcium sulfonate complex thickener. Cat Multipurpose Marine Grease is formulated for use in low to high severity and moderate temperatures. Cat Multipurpose Marine Grease is recommended for use in many types of equipment operating in corrosive and water-related environments. Cat Multipurpose Marine Grease adheres to surfaces strongly and offers high corrosion resistance. The corrosion resistance of this product has been proven by passing over 4000 hours of standard salt spray testing.

Note: If the application calls for a multipurpose marine grease and Cat Multipurpose Marine Grease is not available, consult the grease data sheets. Use an alternative grease that meets or exceeds the performance characteristics of Cat Multipurpose Marine Grease.

Grease Application Charts

Type of Grease

Characteristics of Cat greases and applications conditions are given in Table 13 in this chapter.

The notes below provide an explanation of the terms used in the Table.

Severe Applications are with heavy loads, frequent oscillations, and heavy shock loads.

Extreme pressure (EP) refers to 4-Ball Weld point in the technical data sheet ("ASTM D 2596").

N/R = Not Recommended

Table 12

Type of Cat Grease							
Cat Grease Name	NLGI Grade	Severe Applications	Severe Applications	Severe Applications	Severe Applications with Extremely Heavy Loads	Severe Applications	Extreme Pressure (EP)
Operating Conditions		Extremely Low to Low Temps	Low to Moderate Temps	Moderate to High Temps	Moderate to High Temps	High to Extremely High Temps	(Anti-Wear Protection)
Optimum Temperature Range		-50° C (-58° F) to -18° C (0° F)	-23° C (-10° F) to 29° C (85° F)	18° C (65° F) to 60° C (140° F)	18° C (65° F) to 41° C (105° F)	38° C (100° F) to 232° C (450° F)	
Multipurpose Grease	2	N/R	N/R	N/R	N/R	N/R	Fair
High Speed Ball Bearing Grease	2	N/R	N/R	N/R	N/R	N/R	N/R
Marine Multipurpose	2	Good	Excellent	Excellent	Excellent	Good	Excellent

Type of Grease (continued)

The notes below provide an explanation of the terms used in the Table.

Pumpability is based on "USS Mobility and Lincoln Ventmeter Tests". Performance may vary depending on lubrication equipment and the length of the lines.

Service Life refers to the percent of change after 100,000 strokes in technical data sheet ("ASTM D 217").

Low environmental impact means that the grease is not formulated to contain Lead, Antimony, Barium, Zinc, Phosphorous, or Chlorine additives.

Corrosion protection is the resistance to salt water and salt spray ("ASTM B 117").

Water washout resistance refers to roll stability with water and the percent of change ("ASTM D 1264").

For additional performance data on these greases refer to this Special Publication, "Reference Material" article.

Table 13

Type of Cat Grease						
Cat Grease Name	NLGI Grade	Low Temp. Pumpability	Service Life	Low Environmental Impact	Corrosion Protection	Water Washout Resistance
Operating Conditions		[In Centralized (Auto-Lube) Systems]	(Shear Stability)			
Optimum Temperature Range						
Multipurpose Grease	2	above -23° C (-10° F)	Good	No	Fair	Fair
High Speed Ball Bearing Grease	2	above -18° C (0° F)	Very Good	No	Good	Good
Marine Multipurpose	2	above -7° C (20° F)	Excellent	Yes	Excellent	Excellent

Fuel Specifications

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General Fuel Information

SMCS Code: 1250; 1280

NOTICE

Every attempt is made to provide accurate, up-to-date information. By the use of this document, you agree that Caterpillar Inc. is not responsible for errors or omissions.

The information provided are the latest recommendations for the Cat diesel engines that are covered by this Special Publication. This information supersedes all previous recommendations which have been published for the Cat diesel engines that are covered by this Special Publication. Special fluids are required for some engines and continued will be necessary. Refer to the applicable Operation and Maintenance Manual.

This publication is a supplement to the Operation and Maintenance Manual. This publication does not replace the engine Operation and Maintenance Manuals.

NOTICE

These recommendations are subject to change without notice. Consult your local Cat dealer for the most up to date recommendations.

NOTICE

In order to avoid potential damage to your Cat machine and/or Cat engine, only purchase Cat fluids and Cat filters through your Cat dealer or Cat authorized outlets. For a list of authorized Cat parts outlets in your area, consult your Cat dealer.

If you purchase what appear to be Cat fluids and/or Cat filters through other outlets/sources, you are at a very high risk of purchasing counterfeit ("look-alike") products.

Counterfeit or "look-alike" products may visually appear the same as the original Cat product, but the product performance and internal quality will typically be very low.

Counterfeit or "look-alike" products have a very high likelihood of causing and/or allowing engine and/or machine compartment damage.

Follow all industry standard safety practices when operating engines and/or machines and when performing all recommended and/or required maintenance.

Note: Instructions for the installation of the filter are printed on the side of each Cat spin-on filter. For non-Cat filters, refer to the installation instructions that are provided by the supplier of the filter.

NOTICE

In order to meet expected fuel system component life, 4 micron(c) absolute or less secondary fuel filtration is required for all Cat diesel engines that are equipped with common-rail fuel systems. Also, 4 micron(c) absolute or less secondary fuel filtration is required for all Cat diesel engines that are equipped with unit injected fuel systems. For all other Cat diesel engines (mostly older engines with pump, line and nozzle type fuel systems), the use of 4 micron(c) absolute or less secondary fuel filtration is strongly recommended. Note that all current Cat diesel engines are factory equipped with Cat Advanced Efficiency 4 micron(c) absolute fuel filters.

In order to obtain additional information on Cat designed and produced filtration products, refer to the "Reference Material" article, "Filters" and "Miscellaneous" topics in this Special Publication. Consult your Cat dealer for assistance with filtration recommendations for your Cat machine.

NOTICE

Caterpillar does not warrant the quality or performance of non-Caterpillar fluids and filters.

General Recommendations and Guidelines

Follow all applicable industry standards and all applicable governmental, environmental, and safety guidelines, practices, regulations, and mandates.

Note: These general recommendations and guidelines concerning maintenance and care of fuel and fuel storage systems are not intended to be all inclusive. **Discuss proper fuel safety and health, handling, and maintenance practices with your fuel supplier.** Use of these general recommendations and guidelines does not lessen the engine owners and/or fuel supplier responsibility. All industry standard practices for fuel storage and for fuel handling must be followed.

Note: Where recommendations for draining water and/or sediment and/or debris are stated, dispose of this waste according to all applicable regulations and mandates.

Note: Cat filters are designed and built to provide optimal performance and protection of the fuel system components.

- Discuss application-specific fuel concerns, needs, and requirements with a reputable fuel supplier.
- Purchase fuel from a reputable supplier.
- Use fuel that meets or exceeds Cat requirements for distillate diesel fuel. Refer to the "Cat Specification for Distillate Diesel Fuel for Nonroad Diesel Engines" table in this Special Publication, "Distillate Diesel Fuel" article.
- Confirm with the filter manufacturer that the fuel filter/filters to be used are compatible with the fuel type that will be filtered.
- Follow all the "Contamination Control Recommendations for Fuels" that are provided in this chapter. Dispense fuels of "ISO 18/16/13" cleanliness level or cleaner into the machine or engine fuel tank as detailed in the "Contamination Control Recommendations" section.
- Follow all industry standard grounding and other safety practices.
- Test for microbial contamination on a regular basis and take proper corrective action if contamination is present. Properly dispose of cleanup waste according to all applicable regulations and mandates.
- Every 3 months, or sooner if problems are suspected, have a complete analysis of the bulk storage fuel per the "Cat Specification for Distillate Diesel Fuel for Nonroad Diesel Engines" table in this Special Publication, "Distillate Diesel Fuel" article. Take corrective action if necessary. Corrective actions may include treating the fuel, cleaning of the fuel storage tank/system, and replacing the problematic fuel with fresh fuel.
- Keep the fuel storage tank clean of water, debris, and sediment.
- Drain water and sediment from the fuel storage tank weekly. Drain water and sediment before the tank is refilled.
- Keep the area around the fuel tank filler neck clean of debris in order to prevent contamination of the fuel tank.
- As required, clean the inside of the engine fuel tank and the inside of the bulk storage fuel tank.
- Drain water and sediment from the engine fuel tank daily. Drain water and sediment from the tank at the start of each shift. After the fuel tank has been filled, allow the fuel to settle for 10 minutes. The water and sediment will separate from the fuel. Then, drain the water and sediment from the tank.
- Install fuel/water separators at the bulk storage fuel tank dispensing point and install fuel/water separators on the engine. Wire mesh media is NOT recommended.
- Drain the water from the fuel/water separators daily.
- Cat Advanced Efficiency fuel filters are required for distillate fueled diesel engines in order to provide maximum life to the fuel system.
- Change fuel filters at the scheduled interval. Never fill the new secondary fuel filter with fuel before installation. Use the fuel priming pump to remove air from the system.
- Install and properly maintain four micron(c) absolute breather filters on the engine fuel tank vent. Install and properly maintain four micron(c) absolute breather filters on the bulk storage fuel tank vent. Desiccant type breather vent filters are also recommended in order to remove moisture from air entering the fuel tank. Breather filters are typically changed every 6 months, and desiccant type breather filters are typically changed on saturation. Refer to the literature that was included with the filter. Discuss the availability of desiccant breather vent filters for your application with your filter supplier.
- Top off fixed roof fuel tanks as often as practical. Keeping the tank full reduces the amount of condensation generated water.
- Protect fuel tanks from dirt and water entry.

NOTICE

Do not add new engine oil, waste engine oil or any oil product to the fuel unless the engine is designed and certified to burn diesel engine oil (for example Caterpillar ORS designed for large engines). Caterpillar experience has shown that adding oil products to Tier 4 engine fuels (U.S. EPA Tier 4 certified), to EURO Stage IIB and IV certified engine fuels, or to the fuels of engines equipped with exhaust aftertreatment devices, will generally cause the need for more frequent ash service intervals and/or cause loss of performance.

Adding oil products to the fuel may raise the sulfur level of the fuel and may cause fouling of the fuel system and loss of performance.

Note: Cat has four different size coalescer type fuel filters available for bulk storage fuel tank applications that filter both dirt and water. The filter elements are rated at four microns(c) absolute. Consult your Cat dealer for information on the coalescer filters available through Cat.

Note: The fuel storage tanks must be cleaned thoroughly before converting to Ultra Low Sulfur Diesel (ULSD) (15 ppm or less sulfur) and/or biodiesel/biodiesel blends. Conversion to ULSD and/or biodiesel/biodiesel blends can loosen fuel system and fuel storage tank deposits. Bulk tank continuous filtration unit and dispensing point filters, and onboard engine filters change intervals should be shortened to allow for this cleaning effect.

Note: Cat strongly recommends the filtration of distillate diesel fuel and/or biodiesel/biodiesel blends through a filter with a rating of four microns(c) absolute or less. This filtration should be located on the device that dispenses the fuel to the fuel tank for the engine. Also, filter the fuel from the bulk storage tank. Series filtration is recommended.

Note: Follow all fuel storage maintenance practices that are relevant to your application. Cat recommends a maximum of 1 year from production for distillate fuel storage. A maximum of 6 months from production for biodiesel and blended biodiesel storage is recommended. Storage life for biodiesel and biodiesel blends that are greater than B20 may be much shorter than 6 months.

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Fuel Information for Diesel Engines

SMCS Code: 1250; 1280

NOTICE

U.S. EPA regulations require the use of Ultra Low Sulfur Diesel fuel (ULSD) , ≤ 0.0015 percent (≤ 15 ppm (mg/kg)) sulfur, for nonroad and stationary Tier 4 EPA certified engines using fuel sensitive technologies such as SCR systems and particulate filters. Fuels other than ULSD can cause damage in those engines and should not be used.

Consult the U.S. EPA for fuel sulfur regulations and for the ULSD point of sales required dates for various nonroad applications.

European sulfur free fuel ≤ 0.0010 percent (≤ 10 ppm (mg/kg) sulfur) fuel is required by regulation for use in engines certified to EU nonroad Stage IIIB and newer standards and that are equipped with exhaust aftertreatment systems.

Certain governments/localities and/or applications MAY require the use of ULSD fuel. Consult federal, state, and local authorities for guidance on fuel requirements for your area.

Typical aftertreatment systems include Diesel Particulate Filters (DPF), Diesel Oxidation Catalysts (DOC), Selective Catalytic Reduction (SCR) and/or Lean NOx Traps (LNT). Other systems may apply.

Low sulfur diesel (LSD) fuel (≤ 500 ppm (mg/kg) sulfur) is strongly recommended for use in engines that are pre-Tier 4 models while diesel fuel with >500 ppm sulfur is acceptable for use in areas of the world where allowed by law. Pre-Tier 4 engines that are equipped with a Diesel Oxidation Catalyst (DOC) require the use of LSD fuel or ULSD fuel.

ULSD fuel or sulfur-free diesel fuel are acceptable in all engines regardless of the engine U.S. EPA Tier or EU Stage requirements.

Use appropriate lubricating oils that are compatible with the engine certification and aftertreatment system and with the fuel sulfur levels. Refer to the "Diesel Fuel Sulfur Impacts" article of this "Fuels Specifications" section and to the "Lubricants Specifications" section of this Special Publication.

The two basic types of distillate diesel fuel are No. 2 diesel fuel and No. 1 diesel fuel. No. 2 diesel fuel is the most commonly available summer grade diesel fuel. No. 1 diesel fuel is a winter grade diesel fuel. During the winter months fuel suppliers will typically blend No. 1 and No. 2 diesel fuel in various percentages. Blending allows the fuel to meet the historical low ambient temperature cold-flow needs for a given area or region. No. 2 diesel fuel is a heavier diesel fuel than No. 1 diesel fuel. In cold weather, heavier fuels can cause problems with fuel filters, fuel lines, fuel tanks, and fuel storage. Heavier diesel fuels such as No. 2 diesel fuel can be used in diesel engines that operate in cold temperatures with an appropriate amount of a proven pour point depressant additive. For more information on fuels which include blends of No. 1 and No. 2 diesel fuel, consult your fuel supplier.

When you use No. 2 diesel fuel or other heavier fuels, some of the fuel characteristics may interfere with successful cold-weather operation. Additional information about the characteristics of diesel fuel is available. This information contains a discussion on the modification to the characteristics of diesel fuel. There are several possible methods that can be used to compensate for the fuel qualities that may interfere with cold-weather operation. These methods include the use of starting aids, engine coolant heaters, fuel heaters, and de-icers. In addition, the manufacturer of the fuel can add cold flow improvers and/or blend No. 1 and No. 2 diesel in various percentages.

Not all areas of the world classify diesel fuel using the No. 1 and No. 2 nomenclature described above. But, the basic principles of using additives and/or blending fuels of different densities are the same.

Starting Aids

The use of a starting aid is a conventional method of assistance for cold starts in low temperature conditions. Various starting aids are available for Cat engines. Follow the recommendations that are provided by the manufacturer of the starting aid. Refer to the foreword section in this Special Publication, "Aftermarket Products and Warranty" article.

Engine Coolant Heaters

These heaters heat the engine coolant. The heated coolant flows through the cylinder block. The flow of heated coolant keeps the engine warm. A warm engine is easier to start in cold weather. Most coolant heaters use electrical power. A source of electricity is necessary for this type of heater. Other heaters that burn fuel are available as a source of heat. These heaters may be used in place of the electrical heaters.

With either type of heater, starting aids and/or fuels with higher cetane numbers are less important because the engine is warm. Problems with fuel cloud point can cause the plugging of fuel filters. Problems with fuel cloud point cannot be corrected by engine coolant heaters. Some fuel filters are cooled by air flow during operation.

Fuel Heaters

The fuel cloud point is related to problems with fuel filters. The fuel heater heats the fuel above the cloud point before the fuel enters the fuel filter. Heating prevents wax from blocking the filter. Fuel can flow through pumps and lines at temperatures below the cloud point. The cloud point is often above the pour point of a fuel. While the fuel can flow through these lines, the wax in the fuel can still plug the fuel filter.

In some engine installations, small modifications can prevent problems that are caused by the cloud point. One of the following changes can prevent problems in many conditions: a change in the location of fuel filters and/or supply lines and the addition of insulation. In extreme temperatures, heating of the fuel may be required to prevent the filters from plugging. There are several types of fuel heaters that are available. The heaters typically use either engine coolant or exhaust gas as a heat source. These systems may prevent filter waxing problems without the use of de-icers or cold flow improvers. These systems may be ineffective when the fuel contains a large amount of dirt or of water. Use of a fuel heater can help eliminate some cold-weather problems. A fuel heater should be installed so that the fuel is heated before flowing into the fuel filter.

Note: A fuel heater is not effective for cold-soaked starts unless the fuel heater can be powered from an external power source. External fuel lines may require the use of heaters that circulate the fuel.

Note: Only use properly sized fuel heaters that are controlled by thermostats or use fuel heaters that are self-regulated. Thermostatically controlled fuel heaters generally heat fuel to 15.5° C (60° F). Do not use fuel heaters in warm temperatures.

For distillate fuel configured engines, Cat recommends a fuel viscosity as delivered to rotary fuel injection pumps of between 1.4 cSt and 4.5 cSt. For all other fuel injection pumps, the viscosity must be between 1.4 cSt and 20 cSt.

Note: If a fuel with a low viscosity is used, cooling of the fuel may be required to maintain 1.4 cSt or greater viscosity at the fuel injection pump. Fuels with a high viscosity might require fuel heaters in order to lower the viscosity to the proper level.

NOTICE

When you use fuel heaters, do not allow the fuel temperature to reach above 52°C (125°F). Never exceed 75°C (165°F) with straight distillate fuel. The high fuel temperatures affect the fuel viscosity. When the fuel viscosity falls below 1.4 cSt, pump damage may occur.

WARNING

Overheating the fuel or the fuel filter can result in personal injury and/or damage to the engine. Use extreme care and caution for heating of the fuel and/or the fuel filter.

Select a fuel heater that is mechanically simple, yet adequate for the application. The fuel heater should also prevent overheating of the fuel. Disconnect the fuel heater or deactivate the fuel heater in warm weather. An unacceptable loss of fuel viscosity and engine power will occur if the fuel supply temperature is allowed to become too hot.

For additional information on fuel heaters, consult your Cat dealer.

De-icers

De-icers lower the freezing point of the moisture in the fuel. De-icers are not needed when fuel heaters are used. If you experience trouble, consult your fuel supplier for recommendations of a compatible commercial de-icer.

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Characteristics of Diesel Fuel

SMCS Code: 1250; 1280

Viscosity

The viscosity of the fuel is significant because the fuel serves as a lubricant for fuel system components. Fuels need to have sufficient viscosity. The fuel must lubricate the fuel system in both extremely cold and in extremely hot temperatures. If the kinematic viscosity of the fuel is lower than 1.4 cSt as supplied to the fuel injection pump or unit injectors, excessive scuffing and seizure can occur.

For distillate fuel configured engines, Cat recommends a fuel viscosity as delivered to rotary fuel injection pumps of between 1.4 cSt and 4.5 cSt, and between 1.4 cSt and 20 cSt for all other fuel injection pumps.

If a fuel with a low viscosity is used, cooling of the fuel may be required to maintain 1.4 cSt or greater viscosity at the fuel injection pump. Fuels with a high viscosity might require heaters to lower the viscosity to either 4.5 cSt or less for rotary fuel injection pumps or 20 cSt or less for all other fuel injection pumps.

Cetane Number

The cetane number of the fuel effects the ability of the engine to start. Also, the cetane number effects the interval of time before the engine runs smoothly. Generally, an increase of ten in the cetane number will allow the engine to be started at a lower temperature. The starting temperature can be improved approximately 7 to 8°C (12 to 15°F) for every increase of ten in the cetane number. After the engine reaches the normal operating temperature, a change in the cetane from 40 to 50 will have a minimal effect on engine performance.

Most fuels that have a cetane number above 40 will permit acceptable engine starts in warmer outside temperatures. The engine will start satisfactorily with this fuel when the engine is kept warm. The engine can be kept warm by using either a heated enclosure or a properly sized coolant heater.

During average starting conditions, direct injection diesel engines require a minimum cetane number of 40. A higher cetane value may be required for operation in high altitudes or for cold-weather operation. The minimum fuel cetane number that is required for the precombustion chamber (PC) diesel engine is 35.

Modifying the Cetane Number

The cetane number of a fuel can be changed if the fuel is mixed with a fuel that has a different cetane number. Generally, the cetane number of the mixture will be in direct relation to the ratio of the fuels that were mixed. Your fuel supplier can provide the information about the cetane number of a particular fuel.

Additives can also be used to improve the cetane number of a fuel. Additives are evaluated through testing in special test engines. However, the fuel characteristics of additives used to improved fuel cetane number are different than the naturally occurring proper cetane fuel. While both fuels may be rated as having the same cetane number, starting may be different.

Cloud Point

Understand that the cloud point of a fuel is different from the pour point. There is no relationship between cloud point and the pour point. The cloud point is the temperature that allows some of the heavier components in the wax to solidify in the fuel. This wax is not a contaminant in the fuel. The wax is an important element of No. 2 diesel fuel. The wax has a high fuel energy content and the wax has a high cetane value. Removal of the heavier wax lowers the cloud point of the fuel. Removal of the wax also increases the cost because less fuel can be made from the same amount of crude oil. Basically, a No. 1 diesel fuel is formulated by removing the wax from a No. 2 diesel fuel.

The cloud point of the fuel is important because the cloud point can limit the performance of the fuel filter. The wax can alter the fuel characteristics in cold weather. Solid wax can fill the fuel filters. The solidified wax will stop the flow of fuel. Fuel filters are necessary in order to remove dirt from the fuel. The filters block foreign material, and the filters protect the parts for the fuel injection system. Since fuel must flow through the filters, installing a fuel heater is the most practical way to prevent the problem. A fuel heater will keep the fuel above the cloud point as the fuel flows through the fuel system. The fuel heater will permit the wax to flow through the filters with the fuel.

Modifying the Cloud Point

You can lower the cloud point of a diesel fuel by mixing the diesel fuel with a different fuel that has a lower cloud point. No. 1 diesel fuel or kerosene may be used to lower the cloud point of a diesel fuel. The efficiency of this method is not good. The ratio of the mixture does not have a direct relation to the improvement in cloud point. The amount of fuel with low cloud point that is required makes the process less preferable to use.

The following illustration contains a table that can be used to find the necessary mixture for two fuels with different cloud points. In order to use the table, know the exact fuel cloud point of each fuel. This specification can change from one purchase of fuel to the next purchase of fuel. This specification is normally available from personnel at the source of the fuel supply. When fuels that have a lower cloud point are not available, this method cannot be used.

The manufacturer of the fuel can add cold flow improvers to the fuel. Cold flow improvers modify the wax crystals in the fuels. The cold flow improvers do not change the cloud point. However, the cold flow improvers keep the wax crystals small enough to pass through standard fuel filters. For mixing precautions, see the section "Pour Point".

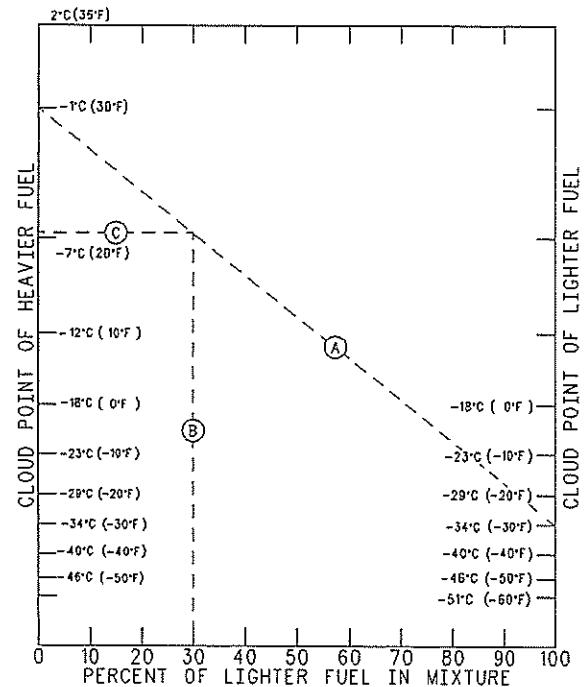


Illustration 1

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Cloud point of fuel mixtures

Use a fuel heater to prevent problems that are caused by fuel cloud point at low temperatures. In most applications, fuel heaters can be used at a lower cost than fuel mixtures.

Pour Point

The fuel pour point is a temperature below the fuel cloud point. Fuel stops flowing below the pour point. The pour point is the temperature which limits movement of the fuel inside of the pumps.

To measure the pour point, the fuel temperature is lowered below the cloud point in steps of 3°C (5°F) at a time. The temperature is lowered until the fuel does not flow. The pour point is the last temperature that is shown before the flow stops. At the pour point, the wax has solidified out of the fuel. The fuel will be more solid than liquid. The pour point of the fuel can be improved without the removal of important elements. This process is the same process that is used to improve the cloud point of a fuel.

A fuel's pour point should be at least 6°C (10°F) below the lowest ambient temperature that is required for engine start-up and for engine operation. To operate the engine in cold weather, No. 1 fuel or No. 1-D fuel may be necessary because of these fuels' lower pour points.

Modifying the Pour Point

You can lower the fuel's pour point by using additives. You can also lower the pour point by mixing the diesel fuel with a fuel that has a lower pour point. No. 1 diesel fuel or kerosene may be used to lower the pour point of a diesel fuel. The amount of fuel with low pour point that is required makes the process less preferable to use.

The following illustration contains a table that can be used to find the necessary mixture for two fuels with different pour points. The fuels do not have additives which change the pour point. In order to use the table, know the exact pour point of each fuel. This specification can change from one purchase of fuel to the next purchase of fuel. This specification is normally available from personnel at the source of the fuel supply. When fuels that have a lower pour point are not available, this method cannot be used.

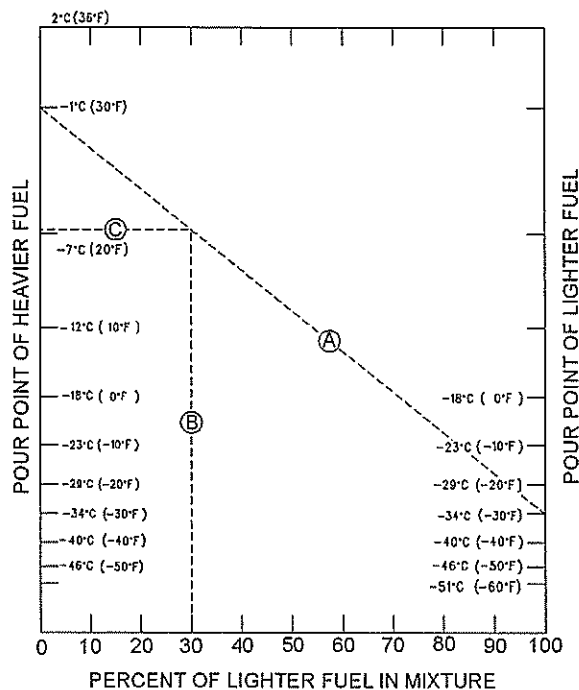


Illustration 2

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Pour point of fuel mixtures

In order to calculate the amount of lighter fuel that is required to be blended with the heavier fuel, perform the following steps:

1. Obtain the specification for the cloud point or the pour point of both fuels from your fuel supplier.
2. Locate the cloud point or the pour point of the heavier fuel on the left side of the table. Mark the point on the table.

3. Locate the cloud point or the pour point of the lighter fuel on the right side of the table. Mark the point on the table.
4. Draw a line between the two points that were established. Label this line "A".
5. Determine the lowest outside temperature for machine operation. Find this point on the left side of the table. Mark this point. Draw a horizontal line from this point. Stop the line at the intersection of line "A". Label this new line "C".
6. Line "C" and line "A" intersect. Mark this point. Draw a vertical line from this point. Stop the line at the bottom of the table. Label this line "B". The point at the bottom of line "B" reveals the percentage of lighter fuel required to modify the cloud point or the pour point.

The above example shows that the blending will require a 30 percent mixture of lighter fuel.

Additives are a good method to use in order to lower the pour point of a fuel. These additives are known by the following names: pour point depressants, cold flow improvers, and wax modifiers. When the additives are used in the proper concentration, the fuel will flow through pumps, lines, and hoses.

Note: These additives must be mixed thoroughly into the fuel at temperatures that are above the cloud point. The fuel supplier should be contacted in order to blend the fuel with the additives. The blended fuel can be delivered to your fuel tanks.

Lubricity and Low Sulfur Diesel (LSD) and Ultra Low Sulfur Diesel (ULSD) Fuel

In the United States (U.S.), LSD will have 0.05 percent (500 ppm(mg/kg)) maximum sulfur. ULSD will have 0.0015 percent (15 ppm(mg/kg)) maximum sulfur. Refer to this Special Publication, "Distillate Diesel Fuel" article for additional information. Also, refer to the most current revision level of "ASTM D975 (Standard Specification for Diesel Fuel Oils)" for additional information.

Note: "ASTM D975" currently allows up to 5 percent biodiesel blends. Refer to the "Fuel Specifications" section and this Special Publication, "Biodiesel" topic for guidance when biodiesel will be used.

In Europe, sulfur free diesel fuel will have 0.0010 percent (10 ppm(mg/kg)) maximum sulfur. Refer to the most current revision level of "European Standard EN 590 (Automotive Fuels - Diesel - Requirements and Test Methods)" for additional information.

Note: "EN 590" currently allows up to 5 percent biodiesel blends. Refer to the "Fuel Specifications" section and this Special Publication, "Biodiesel" topic for guidance when biodiesel will be used.

Note: The fuel lubricity is important. Consider the fuel lubricity whenever you operate the equipment in temperature extremes, whether hot or cold. Also, consider the fuel lubricity whenever you use fuels that are lower in viscosity or that have been hydrotreated. There are many aftermarket additives that are available to treat fuel. If the fuel lubricity is an issue, consult your fuel supplier for proper recommendations regarding fuel additives. Also, refer to this Special Publication, "Distillate Diesel Fuel" article, "Aftermarket Fuel Additives" and "Cat Diesel Fuel Conditioner" topics.

The fluid lubricity describes the ability of the fluid to reduce the friction between surfaces that are under load. This ability reduces the damage that is caused by friction. Fuel injection systems rely on the lubricating properties of the fuel. Until fuel sulfur limits were mandated, the fuel lubricity was believed to be a function of fuel viscosity.

In order to determine the lubricity of the fuel, use the "ASTM D6079 High Frequency Reciprocating Rig (HFRR)" test. The maximum allowable wear scar is 0.52 mm (0.0205 inch) at 60° C (140° F). If the lubricity of a fuel does not meet the minimum requirements, consult your fuel supplier. Do not treat the fuel without consulting the fuel supplier. Some additives are not compatible. These additives can cause problems in the fuel system.

The process that is most commonly used to remove sulfur from fuel is called hydro-treatment. This process is also the most economical process. Each source of crude oil contains different amounts of sulfur. Crude oils typically require hydro-treatment to obtain the 0.0015 percent maximum sulfur limit. Crude oils with high sulfur require a more severe treatment.

The hydro-treatment removes the fuel sulfur as well as other components. The treatment removes nitrogen compounds, polar materials, bicyclic aromatics, polycyclic aromatics, and oxygen compounds. While the removal of sulfur has shown no detrimental effects to the engine, the removal of other compounds have lowered the lubricity of the fuel. As a result of the lowered lubricity, the fuel is less tolerant of contamination by water and dirt. The lower fuel lubricity can be seen as abrasive wear of fuel system components. Fuels that have a low lubricity may not provide adequate lubrication to plungers, to barrels, and to injectors. This problem may be compounded in areas that require winter blends of fuel. The lighter winter fuel blend has the following characteristics: lower viscosity, lower cloud point, and lower pour point.

When required, the fuel lubricity may be enhanced with additives. Many fuel suppliers treat the fuel with these additives. Do not use a fuel lubricity additive before you consult the fuel supplier. Some aftermarket additives may not be compatible with the additives that are already in the fuel, and some may damage emission control systems. Some additive packages may not be compatible with the seals that are used in fuel systems of some diesel engines. Other additive packages that are supplied by aftermarket manufacturers cannot provide proper performance in high temperature conditions. These additives may leave deposits because of the high temperatures that exist in the fuel systems of diesel engines.

Maximum life of the fuel system can be achieved by performing the following tasks: using a preferred distillate diesel fuel (refer to the "Fuel Recommendations" article in this Special Publication), using a reliable fuel supplier, and performing proper maintenance of the fuel system. Cat Advanced Efficiency fuel filters are required for diesel engines that run on diesel fuel in order to provide maximum life to the fuel system.

Note: Lighter fuels are frequently used in arctic temperatures. Lighter fuels may include the following fuels: Jet A, Jet A-1, JP-8, JP-5, and kerosene. The specifications that apply to these fuels do not include a minimum lubricity requirement. Do not assume that a fuel meets the minimum Cat specification. Contact the fuel supplier for proper recommendations on fuel lubricity additives.

Note: The sulfur levels for Jet A, Jet A-1, JP-8, JP-5, and kerosene fuels typically far exceed 15 ppm, the U.S. ULSD fuel and far exceed the EU sulfur free fuel.

Note: For best results, your fuel supplier should treat the fuel when additives are required.

Refer to this Special Publication, "Distillate Diesel Fuel" article, "Aftermarket Fuel Additives", "Cat Diesel Fuel Conditioner", and "Alternative Fuels - Arctic Applications" topics for guidance.

Diesel Fuel Sulfur

Sulfur is a natural component of diesel fuels. High sulfur in the fuel can be reduced through refining technologies.

Sulfur levels in the fuel affect the durability of engine components and also affect engine exhaust emissions. Modern Cat diesel engines are designed to meet mandated gaseous emissions requirements. To meet these emissions requirements, the engines are tested and developed with specific sulfur levels in the diesel fuel.

The maximum allowable fuel sulfur level is controlled by various emissions laws, regulations, and mandates. Consult federal, state, and local authorities for guidance on fuel requirements for your area.

The list below provides a quick reference for acceptable sulfur levels for diesel fuel that will be used in Cat machine diesel engines but the controlling documents are the engine Operation and Maintenance Manuals, the specific aftertreatment device documentation, and the applicable emissions laws, regulations, and mandates.

- U.S. EPA regulations require the use of Ultra Low Sulfur Diesel fuel (ULSD), ≤ 0.0015 percent (≤ 15 ppm (mg/kg)) sulfur, for nonroad and stationary Tier 4 EPA certified engines using fuel sensitive technologies such as SCR systems and particulate filters. Fuels other than ULSD can cause damage in those engines and should not be used. Consult the U.S. EPA for fuel sulfur regulations and for the ULSD point of sales required dates for various nonroad applications.
- European sulfur free fuel, 0.0010 percent ($= 10$ mg/kg) sulfur, fuel is required by regulation for use in engines certified to EU nonroad Stage IIIB and newer standards and that are equipped with exhaust aftertreatment systems.
- Certain governments/localities and/or applications MAY require the use of ULSD fuel. Consult federal, state, and local authorities for guidance on fuel requirements for your area.

- The maximum allowable fuel sulfur level for most pre-Tier 4 engines that are equipped with DOC (Diesel Oxidation Catalyst) is 0.05 percent (500 ppm (mg/kg)). Some DOC equipped engines require the use of fuel with a maximum of 0.005% (50 ppm (mg/kg)) fuel sulfur. Refer to the engine/machine Operation and Maintenance Manual and refer to the aftertreatment device specific documentation for guidance.
- For machine diesel engines that are retrofitted with an aftertreatment device, refer to the aftertreatment device specific documentation.

Typical aftertreatment systems include Diesel Particulate Filters (DPF), Diesel Oxidation Catalysts (DOC), Selective Catalytic Reduction (SCR) and/or Lean NOx Traps (LNT). Other systems may apply.

In addition to the emission regulations, factors that affect maximum allowed and/or acceptable fuel sulfur level include:

- Engine model/design
- Engine application
- Overall fuel quality
- Using recommended fluids, including but not limited to engine oil quality
- Exhaust aftertreatment device type
- Environmental factors and other site specific operating conditions
- Fuel costs versus risk of shortened engine/engine component life
- Fuel costs versus shortened oil drain intervals
- Maintenance intervals and other maintenance practices

Ultra-Low Sulfur Diesel (ULSD)

The United States (U.S.) Environmental Protection Agency (EPA) defines Ultra-Low Sulfur Diesel (ULSD - S15) as a U.S. diesel fuel with a sulfur content not to exceed 15 parts per million (ppm(mg/kg)) or 0.0015 percent by weight.

ULSD was introduced for the U.S. on-highway diesel engine market in October 2006. ULSD is available since December 2010 for nonroad diesel engines and machines. Refer to the U.S. EPA for the required ULSD point of sales dates for various nonroad applications.

Engines certified to nonroad Tier 4 standards (Stage IV in Europe) and are equipped with fuel sulfur sensitive exhaust aftertreatment systems are designed to run on ULSD only. Use of LSD or fuels higher than 15 ppm (mg/kg) sulfur in these engines will reduce engine efficiency and engine durability and will damage emissions control systems and/or shorten their service interval. Failures that result from the use of fuels are not Cat factory defects. Therefore the cost of repairs would not be covered by a Cat warranty.

ULSD fuel can be used in any engine designed to run on diesel fuel. Cat does not require the use of ULSD in nonroad and machine applications that are not Tier 4/Stage IIIB/Stage IV certified engines and are not equipped with aftertreatment devices. For Tier 4/Stage IIIB/Stage IV certified engines, always follow operating instructions and fuel tank inlet labels, if available, to insure the correct fuels are used.

Note: ULSD has less electrical conductivity than LSD. Follow all industry standard grounding and safety practices.

Sulfur-free Diesel Fuel

In Europe, ultra low sulfur diesel fuel will have a maximum of 0.0010 percent (10 ppm(mg/kg)) sulfur and is typically referred to as "sulfur-free". This sulfur level is defined in "European Standard EN 590:2004".

Low Sulfur Diesel (LSD)

Low Sulfur Diesel (LSD - S500) is defined by the U.S. EPA as a U.S. diesel fuel with sulfur content not to exceed 500 ppm or 0.05 percent by weight.

Note: Both ULSD and LSD must meet the fuel requirements outlined in the most current revision level of "ASTM D975".

Diesel Fuel Sulfur Impacts

Sulfur in the fuel results in the formation of sulfur dioxide (SO₂) and sulfur trioxide (SO₃) gases during the combustion process. When combined with water in the exhaust gas SO₂ and SO₃ can form acids. The acids can impact engine components and engine lubricants.

Sulfur in the exhaust gas can interfere with the operation of aftertreatment devices causing loss of passive regeneration performance, reduced gaseous emission conversion efficiency, and increased particulate matter emissions.

Typical aftertreatment systems include Diesel Particulate Filters (DPF), Diesel Oxidation Catalysts (DOC), Selective Catalytic Reduction (SCR) and/or Lean NO_x Traps (LNT). Other systems may apply.

Use of fuels with higher than recommended and/or maximum allowed fuel sulfur levels can and/or will:

- Increase wear of engine components
- Increase corrosion of engine components
- Increase deposits
- Increase soot formation
- Shorten the time period between oil drain intervals (cause the need for more frequent oil drain intervals)
- Shorten the time interval between aftertreatment device service intervals (cause the need for more frequent service intervals)
- Negatively impact the performance and life of aftertreatment devices (cause loss of performance)
- Reduce regeneration intervals of aftertreatment devices
- Lower fuel economy
- Increase overall operating costs

Depending on operating conditions, and depending on maintenance practices, the potential issues stated above may and/or will take place with fuel sulfur levels that are at or below the recommended fuel sulfur levels, and/or that are at or below the maximum allowable fuel sulfur levels.

Fuel sulfur levels above 0.1% (1000 ppm (mg/kg)) may significantly shorten the oil change interval.

When other factors do not preclude, and understanding that there may be trade-offs such as shortened oil drain intervals, certain commercial and machine diesel engines that are covered by this Special Publication MAY be able to operate satisfactorily on fuels with up to 1 percent (10,000 ppm(mg/kg)) sulfur if the following conditions are met:

- All emissions laws, regulations and mandates are followed
- The engine/engines are not equipped with aftertreatment device/devices
- All appropriate guidelines and maintenance practices as stated in the engine Operation and Maintenance Manual are followed
- All appropriate guidelines and maintenance practices as stated in this Special Publication are followed

- Operating in otherwise low to moderate severity applications
- Your Cat dealer is consulted and approves
- You refer to this Special Publication, and you refer to your specific Cat commercial engine and/or refer to your specific Cat machine Operation and Maintenance Manual for additional guidance and exceptions

Oil Drain Intervals

Note: DO NOT USE ONLY THIS SPECIAL PUBLICATION AS A BASIS FOR DETERMINING OIL DRAIN INTERVALS.

Fuel sulfur level impacts the oil drain interval. For detailed information, refer to the "S·O·S Services Oil Analysis" section in the "Lubricants Specification" article in this Special Publication.

- Cat S·O·S Services oil analysis is recommended.
- Cat S·O·S Services oil analysis is very strongly recommended to determine oil drain intervals when using fuel with sulfur levels between 0.05% (500 ppm) and 0.5% (5000 ppm).
- Cat S·O·S Services oil analysis is required to determine oil drain intervals when using fuel with sulfur levels above 0.5% (5000 ppm).
- Consult your Cat dealer for guidance when fuel sulfur levels are above 0.1% (1000 ppm).

Moisture Content

Problems with fuel filters can occur at any time. The cause of the problem can be water in the fuel or moisture in the fuel. At low temperatures, moisture causes special problems. There are three types of moisture in fuel: dissolved moisture (moisture in solution), free and dispersed moisture in the fuel, and free and settled at the bottom of the tank.

Most diesel fuels have some dissolved moisture. Just as the moisture in air, the fuel can only contain a specific maximum amount of moisture at any one temperature. The amount of moisture decreases as the temperature is lowered. For example, a fuel could contain 100 ppm(100 mg/kg or 0.010 percent) of water in solution at 18°C (65°F). This same fuel can possibly hold only 30 ppm(30 ppm or 0.003 percent) at 4°C (40°F).

After the fuel has absorbed the maximum amount of water, the additional water will be free and dispersed. Free and dispersed moisture is fine droplets of water that is suspended in the fuel. Since the water is heavier than the fuel, the water will slowly become free and settled at the bottom of the tank. In the above example, when the fuel temperature was lowered from 18°C (65°F) to 4°C (40°F), 70 ppm(mg/kg) of water became free and dispersed in the fuel.

The small drops of water cause a cloudy appearance in the fuel. If the change in temperature is slow, the small drops of water can settle to the bottom of the tank. When the fuel temperature is lowered rapidly to freezing temperature, the moisture that comes out-of-solution changes to fine particles of ice instead of small drops of water.

The particles of ice are lighter than the fuel, and the particles of ice will not settle to the bottom of the tank. When this type of moisture is mixed in the fuel, this moisture will fill the fuel filters. The ice crystals will plug the fuel filters in the same way as wax plugs the fuel filters.

If a filter is plugged and fuel flow is stopped, perform the following procedure to determine the cause:

1. Remove the fuel filters.
2. Cut the fuel filters open.
3. Inspect the fuel filter before the filter warms. This inspection will show that the filter is filled with particles of either ice or wax.

The moisture which is free and settled at the bottom of the tank can become mixed with the fuel. The force of any pumping action will mix the moisture with the fuel whenever fuel is transferred. This moisture then becomes free and dispersed water. This moisture can cause ice in the filters. This moisture can cause other problems with filters at any temperature. Generally, the same force that mixes the water into the fuel will also mix dirt and rust from the bottom of the tank. The result is a dirty mixture of fuel and water which can also fill the filters and stop fuel flow.

Specific Gravity / API Gravity

The specific gravity of diesel fuel is the weight of a fixed volume of fuel in comparison to the weight of the same volume of water at the same temperature. A higher specific gravity correlates into a heavier fuel. Heavier fuels have more energy or power per volume for the engine to use.

Note: The settings for the fuel mixture should not be adjusted in order to compensate for a loss of power with fuels that are lighter. The life of fuel system components can be decreased with light fuels because lubrication will be less effective as a result of the lower viscosity. Sufficient lubricity is a problem. Refer to the "Lubricity and Low Sulfur Fuel Diesel (LSD) and Ultra Low Sulfur Diesel (ULSD) Fuel" topic in this Special Publication, "Characteristics of Diesel Fuel" article.

The API gravity of a fuel is also a measure of the density of the fuel or the relationship of the weight to the volume. The scale for API gravity is inverse to the scale for specific gravity. The API gravity will become higher as the fuel becomes lighter.

Lighter fuels will not produce the rated power. Lighter fuels may also be a blend of ethanol or methanol with diesel fuel. Blending alcohol or gasoline with diesel fuel will create an explosive atmosphere in the fuel tank. In addition, water condensation in the tank can cause the alcohol to separate in the tank.



WARNING

Mixing alcohol or gasoline with diesel fuel can produce an explosive mixture in the engine crankcase or fuel tank.

Personal injury and damage to the engine may result. Caterpillar recommends against this practice.

NOTICE

Mixing alcohol or gasoline with diesel fuel may cause damage to the engine. Caterpillar recommends against this practice. Water condensation in the fuel tank can cause the alcohol to separate which could cause damage to the engine.

Heavier fuels tend to create more deposits from combustion. Deposits from combustion can cause abnormal cylinder liner and ring wear. Wear is most noticeable in smaller diesel engines that operate at higher speeds.

Gums and Resins

The gums and resins that occur in diesel fuel are the result of dissolved oxidation products in the fuel that do not evaporate easily. The products that are dissolved in the fuel also do not burn cleanly. Excessive gum in the fuel will coat the inside of fuel lines, pumps, and injectors. Excessive gum will also interfere with the close tolerances of the moving parts of the fuel systems. Gum and resin in the fuel will also cause the filter to plug rapidly. Oxidation of the fuel will occur and the formation of additional gums and resins will occur during fuel storage. The storage time for fuel must be minimized in order to help reduce the formation of gums and resins.

Note: Even when all fuel storage maintenance practices are followed, Cat recommends a maximum of 1 year from production for distillate diesel fuel storage, and a maximum of 6 months from production for biodiesel and blended biodiesel storage. Storage life for biodiesel and biodiesel blends that are greater than B20 may be much shorter than 6 months.

The Thermal Stability and Oxidation Stability of Fuel

Diesel fuels can deteriorate rapidly for various reasons. When the fuel is stressed and stored for long intervals, degradation and oxidation can occur. Degradation and oxidation are complex chemical changes. These changes lead to deposits or sediment from certain hydrocarbons and traces of naturally occurring nitrogen and sulfur containing compounds in the fuel. Fuel composition and environmental factors influence the process.

Diesel fuel is being used as a coolant for high-pressure fuel injection systems with high temperature fuel wetted walls. The fuel in the fuel system will be stressed. The thermal stress and an increase in recirculation fuel temperature is often responsible for fuel degradation. Gums, resins, sediment, and deposits will form, which can cause fuel flow restriction through fuel filters and fuel injection systems.

Certain products are often stored for long periods with the fuel in the fuel system. The fuel is exposed to oxygen. Complex reactions between the oxygen and the fuel components can generate fuel particulates. The particulates in the fuel system can turn into the sludge that is found in fuel tanks, fuel lines, and the fuel filters. The performance of the fuel system will deteriorate. Degradation also leads to a plugged fuel filter, a restriction to the fuel line and deposit formation in the fuel injection nozzle.

Biodiesel and blends of biodiesel have poor thermal stability and oxidation stability compared to petroleum distillate diesel fuels. The use of these biodiesels and blends of biodiesel can accelerate the problems that are addressed in this Special Publication. Using biodiesel blends above the maximum level approved for the engine is not recommended.

Thermal and oxidative degradation of diesel fuel can result in a darkening of fuel color. Fuel color is not necessarily an indication of excessive degradation that will lead to the problems outlined in this Special Publication. But darkened fuel color can be an indicator of degradation leading to concerns about the stability of darkened fuel. Thermal oxidation and oxidative stability tests should be run to confirm actual fuel degradation.

Thermal Stability

Cat recommends the use of the "Accelerated Fuel Oil Stability Test (ASTM D6468)". This test method determines the instability of a fuel subjected to a thermal degradation process. This test exposes the fuel to conditions that are similar to actual operating conditions when the fuel cools the injectors during the engine operation.

The test is performed by using a spectrophotometer. The percentage reflectance of fuel should not be less than 80 percent after aging for 3 hours at a temperature of 150° C (302° F).

Oxidative Stability Test

Cat recommends the use of the "Oxidative Stability Test". This test method determines long-term storage of distillate fuels such as home heating oils, kerosene, and diesel oils. The test method is not suitable for highly volatile fuels with flash points under 38° C (100° F). This test method is used for storage stability, with the use of stabilizing additives and without the use of stabilizing additives.

As per the specification "EN590:2004 Automotive Fuels - Diesel", a test for a direct measurement of oxidation stability is the test method "ISO 12205 Petroleum products - Determination of the oxidation stability of middle distillate diesel fuels". The fuel sample is heated at 95° C (203° F) for 16 hours while bubbles of oxygen travel through the sample. The resulting amount of solid oxidation by products is then measured. This test simulates the oxidation of fuel during long-term storage. For diesel fuel the maximum amount of insolubles formed should not exceed 25 g per cubic meter.

Cat recommends that for diesel, biodiesel, or biodiesel blends that are going to be used several months after purchase, artificially aging the fuel to predict the storage stability, followed by an analysis of the fuel. For most distillate fuels that age the fuel for 7 days at 80° C (176° F) can simulate storage for 4 to 8 months at typical ambient storage temperatures. Analysis of this matured fuel per the methods discussed in this document can then be used to aid in predicting the stability of the fuel after numerous months of storage. Analysis of Diesel fuel should include "Thermal Stability - ASTM D6468", "Fuel Gums - ASTM D381" and "Fuel Sediments - ASTM D473". Analysis of biodiesel fuel and biodiesel fuel blends should include "Oxidation - EN14112", "Acid Value - ASTM D664", "Viscosity - ASTM D445" and "Sediments - ASTM D2709".

A test that can be used to help determine the degradation of biodiesel fuel and biodiesel fuel blends is the measurement of the "Acid Value - ASTM D664" or "EN 14104". This value represents the amount of acid present in the biodiesel fuel or biodiesel blend fuel as a result of degradation. The required limit for B100 biodiesel is given in "Cat Biodiesel specification" in this Special Publication or in "B100 specification - ASTM D6751". The required limit for B6-B20 biodiesel fuel blend is given in "ASTM D7467" specification.

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Fuel Recommendations

SMCS Code: 1250; 1280

NOTICE

These recommendations are subject to change without notice. Consult your local Cat dealer for the most up to date recommendations.

Diesel engines may burn a wide variety of fuels. These fuels are divided into two general groups. The two groups are called the preferred fuels and the permissible fuels.

The preferred fuels provide maximum engine service life and performance. The preferred fuels are distillate fuels. These fuels are commonly called diesel fuel, furnace oil, gas oil, or kerosene. These fuels must meet the "Cat Specification for Distillate Diesel Fuel for Off-Highway Diesel Engines" found in this Special Publication, "Distillate Diesel Fuel" article.

Note: The permissible fuels are some crude oils, some blends of crude oil with distillate fuel, some biodiesel, and some marine diesel fuel. **These fuels are not suitable for use in all engine applications.** The acceptability of these fuels for use is determined on a case by case basis. A complete fuel analysis is required. Consult your Cat dealer for further information. For information concerning biodiesel/biodiesel blends, refer to this Special Publication, "Biodiesel" article.

Note: Except for some biodiesel, permissible fuels are not acceptable for use in on-highway applications.

NOTICE

Use of permissible fuels can result in higher maintenance costs and reduced engine service life.

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Distillate Diesel Fuel

SMCS Code: 1280

Note: For on-highway diesel engine fluids requirements, refer to specific engine Operation and Maintenance Manuals, and also refer to the most current revision level of Special Publication, SEBU6385, "Caterpillar On-Highway Diesel Engine Fluids Recommendations". Also consult your Cat dealer.

Cat is not in the position to evaluate continuously and monitor all of the many worldwide distillate diesel fuel specifications and on-going revisions that are published by governments and technological societies.

The "Cat Specification for Distillate Fuel for Nonroad Diesel Engines" provides a known, reliable baseline to judge the expected performance of distillate diesel fuels that are derived from conventional sources (crude oil, shale oil, oil sands) when used in Cat diesel engines.

Use the Cat distillate diesel fuel specification as the baseline. Determine any potential economic and/or performance trade-offs and overall acceptability when using fuels of varying characteristics and quality levels.

- When required, have the diesel fuel that either is being used or is planned to use, tested per the Cat distillate diesel fuel specification.
- Use the Cat distillate diesel fuel specification as a fuel quality baseline for comparison of distillate diesel fuel analysis results. Also, use the specification as a baseline for comparison of other distillate diesel fuel specifications.

- Typical fuel characteristics can be obtained from the fuel supplier.

Fuel parameters outside of the Cat fuel specification limits have explainable consequences.

- Some fuel parameters that are outside of the specification limits can be compensated for (for example, fuel can be cooled to address low viscosity).
- Some fuel parameters that are outside of specification limits may improve with the use of appropriate amounts of proven fuel additives. Refer to this Special Publication, "Distillate Diesel Fuel" article, "Aftermarket Fuel Additives" and "Cat Diesel Fuel Conditioner" topics for guidance.

To help ensure optimum engine performance, a complete fuel analysis should be obtained before engine operation. The fuel analysis should include all of the properties that are listed in the "Cat Specification for Distillate Fuel for Nonroad Diesel Engines", Table 14.

Note: The diesel fuel cannot have any visually apparent sediment, suspended matter, or undissolved water.

Diesel Fuels that meet the specifications in table 14 will help provide maximum engine service life and performance.

In North America, diesel fuels that are identified as meeting the latest version of "ASTM D975" Grades No. 1-D or No. 2-D (all listed sulfur levels) generally meet the table 14 requirements.

In Europe, diesel fuels that are identified as meeting the latest version of "European Standard EN590" generally meet the table 14 requirements.

Table 14 is for diesel fuels that are distilled from conventional sources (crude oil, shale oil, oil sands). Diesel fuels from other sources could exhibit detrimental properties that are not defined or controlled by this specification.

NOTICE

Ultra Low Sulfur Diesel (ULSD) fuel 0.0015 percent (≤ 15 ppm (mg/kg)) sulfur is required by regulation for use in engines certified to nonroad Tier 4 standards (U.S. EPA Tier 4 certified) and that are equipped with exhaust aftertreatment systems.

European ULSD 0.0010 percent (≤ 10 ppm (mg/kg)) sulfur fuel is required by regulation for use in engines certified to European nonroad Stage IIIB and newer standards and are equipped with exhaust aftertreatment systems.

Certain governments/localities and/or applications MAY require the use of ULSD fuel. Consult federal, state, and local authorities for guidance on fuel requirements for your area.

Typical aftertreatment systems include Diesel Particulate Filters (DPF), Diesel Oxidation Catalysts (DOC), Selective Catalytic Reduction (SCR) and/or Lean NOx Traps (LNT). Other systems may apply.

Low sulfur diesel (LSD) fuel 0.05 percent (≤ 500 ppm (mg/kg) sulfur) is strongly recommended for use in engines that are pre-Tier 4 models, while diesel fuel with > 0.05 percent (500 ppm (mg/kg)) sulfur is acceptable for use in areas of the world where allowed by law. Pre-Tier 4 engines that are equipped with a Diesel Oxidation Catalyst (DOC) require the use of LSD fuel or ULSD fuel.

ULSD fuel or sulfur-free diesel fuel are applicable for use in all engines regardless of the engine Tier or Stage.

Use appropriate lubricating oils that are compatible with the engine certification and aftertreatment system and with the fuel sulfur levels. Refer to the "Diesel Fuel Sulfur Impacts" article of this "Fuels Specifications" section and to the "Lubricants Specifications" section of this Special Publication.

The overall quality of the fuel is critical to the successful operation of engines.

Engine operating conditions play a key role in determining the effect that fuel sulfur will have on engine deposits and on engine wear. Using fuels with higher than recommended fuel sulfur levels can or will cause various negative impacts. For information on fuel sulfur and fuel sulfur impacts refer to the Diesel Fuel Sulfur article in this Fuel Specifications section.

NOTICE

Do not add new engine oil, waste engine oil or any oil product to the fuel unless the engine is designed and certified to burn diesel engine oil (for example Caterpillar ORS designed for large engines). Caterpillar experience has shown that adding oil products to Tier 4 engine fuels (U.S. EPA Tier 4 certified), to EURO Stage IIIB and IV certified engine fuels, or to the fuels of engines equipped with exhaust aftertreatment devices, will generally cause the need for more frequent ash service intervals and/or cause loss of performance.

Adding oil products to the fuel may raise the sulfur level of the fuel and may cause fouling of the fuel system and loss of performance.

Cat does not require the use of ULSD in Nonroad and machine applications that are not Tier 4/Stage IIIB/ Stage IV certified engines. These engines that are not equipped with aftertreatment devices do not require ULSD. For Tier 4/Stage IIIB/Stage IV certified engines, always follow operating instructions and fuel tank inlet labels to insure the correct fuels are used.

ULSD and any other fuel used in Cat engines have to be properly formulated by the fuel supplier. Fuels must meet Special Publication, "Caterpillar Specification for Distillate Diesel Fuel for Off-Highway Diesel Engines". Fuels that are defined as "ASTM D975" Grade No. 1-D S15 or "ASTM D975" Grade No. 2-D S15 generally meet Cat requirements for ULSD.

Refer to this Special Publication, "Characteristics of Diesel Fuel" article for additional pertinent information concerning fuel lubricity, fuel oxidation stability, fuel sulfur, and aftertreatment devices. Also refer to "ASTM D975-08a", to the specific engine Operation and Maintenance Manual, and to aftertreatment device documentation for guidance.

Note: Cat strongly recommends the filtration of distillate fuel and/or biodiesel/biodiesel blends through a fuel filter with a rating of four microns(c) absolute or less. This filtration should be located on the device that dispenses the fuel to the fuel tank for the engine, and also on the device that dispenses fuel from the bulk storage tank. Series filtration is recommended.

Note: The owner and the operator of the engine has the responsibility of using the correct fuel that is recommended by the manufacturer and allowed by the U.S. EPA and, as appropriate, other regulatory agencies.

NOTICE

Operating with fuels that do not meet Cat recommendations can cause the following effects: starting difficulty, reduced fuel filter service life, poor combustion, deposits in the fuel injectors, reduced service life of the fuel system, deposits in the combustion chamber, and reduced service life of the engine.

NOTICE

The footnotes are a key part of the "Caterpillar Specification for Distillate Diesel Fuel" Table. Read ALL of the footnotes.

For additional guidance related to many of the fuel characteristics that are listed, refer to "Cat Specification for Distillate Fuel for Nonroad Diesel Engines", table 14.

The values of the fuel viscosity given in table 14 are the values as the fuel is delivered to the fuel injection pumps. For ease of comparison, fuels should also meet the minimum and maximum viscosity requirements at 40° C (104° F) that are stated by the use of either the "ASTM D445" test method or the "ISO 3104" test method. If a fuel with a low viscosity is used, cooling of the fuel may be required to maintain 1.4 cSt or greater viscosity at the fuel injection pump. Fuels with a high viscosity might require fuel heaters in order to lower the viscosity to either 4.5 cSt or less for rotary fuel injection pumps or 20 cSt viscosity or less for all other fuel injection pumps.

The lubricity of a fuel is a concern with low sulfur and ultra low sulfur fuel. To determine the lubricity of the fuel, use the "ASTM D6079 High Frequency Reciprocating Rig (HFRR)" test. There are many aftermarket additives that are available to treat fuel. If the lubricity of a fuel does not meet the minimum requirements, consult your fuel supplier for proper recommendations regarding fuel additives. Also, refer to this Special Publication, "Characteristics of Diesel Fuel" article, "Aftermarket Fuel Additives" and "Cat Diesel Fuel Conditioner" topics. Do not treat the fuel without consulting the fuel supplier. Some additives are not compatible. These additives can cause problems in the fuel system.

Table 14

Cat Specification for Distillate Fuel for Nonroad Diesel Engines			
Specifications	Requirements	ASTM Test	ISO Test
Aromatics	35% maximum	"D1319"	"3837"
Ash	0.01% maximum (weight)	"D482"	"6245"

(continued)

(Table 14, contd)

Cat Specification for Distillate Fuel for Nonroad Diesel Engines			
Specifications	Requirements	ASTM Test	ISO Test
Carbon Residue on 10% Bottoms	0.35% maximum (weight)	"D524"	"4262"
Cetane Number ⁽¹⁾	40 minimum (DI engines)	"D613" or "D6890"	"5165"
	35 minimum (PC engines)		
Cloud Point	The cloud point must not exceed the lowest expected ambient temperature.	"D2500"	"3015"
Copper Strip Corrosion	No. 3 maximum	"D130"	"2160"
Distillation	10% at 282 °C (540 °F) maximum	"D86"	"3405"
	90% at 360 °C (680 °F) maximum ⁽²⁾		
	90% at 350 °C (662 °F) maximum ⁽²⁾		
Flash Point	legal limit	"D93"	"2719"
Thermal Stability	Minimum of 80% reflectance after aging for 180 minutes at 150 °C (302 °F)	"D6468"	No equivalent test
API Gravity ⁽³⁾	30 minimum	"D287"	No equivalent test
	45 maximum		
Pour Point	6 °C (10 °F) minimum below ambient temperature	"D97"	"3016"
Sulfur	⁽⁴⁾	"D5453" or "D2622"	"20846" or "20884"

(continued)

(Table 14, contd)

Cat Specification for Distillate Fuel for Nonroad Diesel Engines			
Specifications	Requirements	ASTM Test	ISO Test
Kinematic Viscosity	1.4 cSt minimum and 20.0 cSt maximum as delivered to the fuel injection pumps	-	-
	1.4 cSt minimum and 4.5 cSt maximum as delivered to the rotary fuel injection pumps		
Water and Sediment	0.05% maximum	"D1796" or "D2709"	"3734"
Water	0.05% maximum	"D6304"	No equivalent test
Sediment	0.05% maximum (weight)	"D473"	"3735"
Gums and Resins ⁽⁶⁾	10 mg per 100 mL maximum	"D381"	"6246"
Lubricity	0.52 mm (0.0205 inch) maximum at 60 °C (140 °F)	"D6079"	No equivalent test

(continued)

(Table 14, contd)

Cat Specification for Distillate Fuel for Nonroad Diesel Engines			
Specifications	Requirements	ASTM Test	ISO Test
Cleanliness	⁽⁵⁾	"D7619"	"4406"

- (1) Alternatively, to ensure a minimum cetane number of 35 (PC engines), and 40 (DI engines), distillate diesel fuel should have a minimum cetane index of 37.5 (PC engines), and 44.2 (DI engines) when the "ASTM D4737-96a" test method is used. A fuel with a higher cetane number may be required for operation at a higher altitude or in cold weather.
- (2) Distillation of 90% at 350°C (662°F) maximum is recommended for Tier 4 engines and preferred for all engines. Distillation of 90% at 350°C (662°F) is equivalent to 95% at 360°C (680°F). Distillation of 90% at 360°C (680°F) maximum is acceptable for Pre-Tier 4 engines.
- (3) Via standards tables, the equivalent kg/m³ (kilograms per cubic meter) using the "ASTM D287" test method temperature of 15.56° C (60° F) for the minimum API gravity of 30 is 875.7 kg/m³, and for the maximum API gravity of 45 is 801.3 kg/m³.
- (4) Follow the federal, state, local, and other governing authorities for guidance concerning the fuel requirements in your area. Follow the engine Operation and Maintenance Manual and the details provided in this Fuel section. ULSD 0.0015% (<15 ppm S) is required by law for Tier 4 engines and engines with aftertreatment devices. ULSD and LSD 0.05% (≤500 ppm S) are recommended for pre-Tier 4 engines. Diesel fuel with > 0.05% (>500 ppm) sulfur is acceptable for use where allowed by law. Consult your Cat dealer for guidance when sulfur levels are above 0.1% (1000 ppm). Certain Cat fuel systems and engine components can operate on fuel with a maximum sulfur content of 3%. Refer to the specific engine Operation and Maintenance Manual and consult your Cat dealer.
- (5) Follow the test conditions and procedures for gasoline (motor).
- (6) Recommended cleanliness level for fuel as dispensed into machine or engine fuel tank is "ISO 18/16/13" or cleaner per "ISO 4406" or "ASTM D7619". Refer to the "Contamination Control" section in this Special Publication.

There are many other diesel fuel specifications that are published by governments and by technological societies. Usually, those specifications do not review all the requirements that are addressed in the "Cat Specification for Distillate Fuel for Nonroad Diesel Engines", Table 14. To help ensure optimum engine performance, a complete fuel analysis should be obtained before engine operation. The fuel analysis should include all of the properties that are listed in the "Cat Specification for Distillate Fuel for Nonroad Diesel Engines", Table 14.

NOTICE

In order to meet expected fuel system component life, 4 micron(c) absolute or less secondary fuel filtration is required for all Cat diesel engines that are equipped with common-rail fuel systems. Also, 4 micron(c) absolute or less secondary fuel filtration is required for all Cat diesel engines that are equipped with unit injected fuel systems. For all other Cat diesel engines (mostly older engines with pump, line and nozzle type fuel systems), the use of 4 micron(c) absolute or less secondary fuel filtration is strongly recommended. Note that all current Cat diesel engines are factory equipped with Cat Advanced Efficiency 4 micron(c) absolute fuel filters.

In order to obtain additional information on Cat designed and produced filtration products, refer to this Special Publication, "Reference Material" article, "Filters" and "Miscellaneous" topics, and then contact your Cat dealer for assistance with filtration recommendations for your Cat machine.

**WARNING**

Mixing alcohol or gasoline with diesel fuel can produce an explosive mixture in the engine crankcase or fuel tank.

Personal injury and damage to the engine may result. Caterpillar recommends against this practice.

Diesel Fuels for Marine Engines

The information and guidelines given in the "Diesel Fuel" article of this Special Publication apply to marine engines that use diesel fuels. Follow these guidelines in order to reduce the risk of engine downtime. Refer to your engine Operation and Maintenance Manual for details specific to your marine engine. Consult your Cat dealer for more information.

The International Maritime Organization (IMO) regulates the fuel sulfur level for ocean going ships. Current marine fuels at sea that are regulated by the IMO can have sulfur levels up to 3.5 percent (35,000 ppm) prior to the year 2020. As of 1 January 2020, ships operating in international waters are required to use fuels with sulfur levels below 0.5 percent (5000 ppm).

Furthermore, IMO designates certain areas as Sulfur Emissions Control Areas (SECA). Ships operating within SECA must operate on 1 percent (10,000 ppm) sulfur fuel prior to the year 2015. After 1 January 2015 ships operating within SECA must operate with 0.1 percent (1000 ppm) sulfur fuels. IMO may change areas considered SECA. Review and follow local and IMO requirements and local regulations for planned destinations. Refer to your engine Operation and Maintenance Manual for appropriate marine fuels for use in your engine.

The US Environmental Protection Agency (EPA) regulates the sulfur level of marine fuels in the US waterways and shores. For vessels operating exclusively within US waters, Ultra Low Sulfur Diesel (ULSD) is required by regulations unless local exceptions exist. Vessels traveling internationally under the US Flag are required to operate on ULSD regardless of destination and location. Refer to the regulations in your area of operation. If your destination does not have ULSD, but your engine can operate on fuel other than ULSD, exemptions can be requested by contacting the EPA at the following address:

complianceinfo@epa.gov

Refer to your engine Operation and Maintenance Manual for fuels information for your engine.

Foreign flagged vessels operating in the US are required to follow IMO rules while sailing in US waters designated as SECA. Always refer to the local regulations at ports of call to determine fuel requirements as they are subject to change.

Note: ULSD is backwards compatible and can be used in most engine technologies. Diesel fuels with > 0.0015 percent (>15 ppm) sulfur can be used in engines that do not have aftertreatment devices and where permitted by local regulations.

Heavy Fuel Oil, Residual Fuel, Blended Fuel

NOTICE

Heavy Fuel Oil (HFO), Residual fuel, or Blended fuel must **NOT** be used in Caterpillar diesel engines (except in 3600 Series HFO engines). Blended fuel is residual fuel that has been diluted with a lighter fuel (cutter stock) so that they will flow. Blended fuels are also referred to as heavy fuel oils. Severe component wear and component failures will result if HFO type fuels are used in engines that are configured to use distillate fuel.

Alternative Fuels - Cold Weather Applications

In extreme cold ambient conditions, you may choose to use the distillate fuels that are specified in table 15. However, the fuel that is selected must meet the requirements that are specified in the "Cat Specification for Distillate Diesel Fuel for Nonroad Diesel Engines", Table 14. These fuels are intended for use in operating temperatures that are down to -54°C (-65°F).

Note: The fuels that are listed in table 15 typically have much higher sulfur levels than the 15 ppm maximum sulfur allowed for ULSD. The sulfur levels for these fuels typically far exceed 15 ppm. These fuels typically will not be acceptable for use in areas that restrict maximum fuel sulfur levels to 15 ppm or less.

Note: The fuels that are listed in table 15 typically have much higher sulfur levels than the 50 ppm maximum sulfur allowed in the European Standard "EN 590:2004". The sulfur content of these fuels typically far exceeds 50 ppm. These fuels typically will not be acceptable for use in areas that restrict maximum fuel sulfur levels to 50 ppm or less.

The fuel that is selected must meet the requirements that are specified in "Cat Specification for Distillate Diesel Fuel for Nonroad Diesel Engines", table 14. Cooling of the fuel may be required to maintain 1.4 cSt or greater viscosity at the fuel injection pump. Consult the supplier for the recommended additives in order to maintain the proper fuel lubricity.

This table lists fuel specifications for fuel additives that have not been tested by Cat for use in Cat fuel systems. The use of these specifications allowed and/or recommended fuel additives are at the risk of the user.

Jet A is the standard fuel used by U.S. commercial airlines when operating within the U.S.. Jet A-1 is the standard fuel used by commercial airlines worldwide. Per "ASTM D1655-08a, Table 1 (Detailed Requirements of Aviation Turbine Fuels)". Jet A and Jet A-1 have identical requirements except for freezing point. Jet A has a freeze point requirement of -40°C (-40°F) versus the Jet A-1 has a freeze point requirement of -47°C (-52.6°F), but the fuel purchaser and the fuel supplier may agree on other freezing points.

Table 15

Alternative Distillate Fuels - Cold Weather Applications	
Specification	Grade
"MIL-DTL-5624U"	JP-5
"MIL-DTL-83133F"	JP-8
"ASTM D1655-08a"	Jet A, Jet A-1

These fuels are lighter than the No. 2 grades of fuel. The cetane number of the fuels in table 15 must be at least 40. If the viscosity is below 1.4 cSt at 40°C (104°F), use the fuel only in temperatures below 0°C (32°F). Do not use any fuels with a viscosity of less than 1.2 cSt at 40°C (104°F).

Note: Fuel cooling may be required in order to maintain the minimum viscosity of 1.4 cSt at the fuel injection pump.

Note: These fuels may not prove acceptable for all applications.

Renewable and Alternative Fuels

Renewable fuels are derived from renewable resources such as planted crops and crop residues (referred to as biomass), waste, algae, cellulosic material, yard, and food waste, and so on. Renewable fuels reduce the carbon footprint of the fuels compared to fossil fuels on a Life Cycle Analysis basis. Cat, through sustainability initiatives, supports the development and use of renewable fuels.

Renewable fuels (other than biodiesel) and alternative fuels (such as but not limited to Gas-to-Liquid fuel) are typically hydrocarbons (composed of carbon and hydrogen). An exception is biodiesel, which is an oxygenated renewable fuel. Biodiesel is discussed in a separate article in this Fuel section. Significant research is on going to develop renewable fuels and production economy.

Cat is not in a position to test all varieties of renewable and alternative fuels that are advertised in the market place. Before operating on any fuels other than diesel fuel or biodiesel (as discussed in this Fuels section), consult with the fuel supplier and with your Cat dealer. Due to the nature of the hydrocarbons that make up some alternative fuels in the marketplace, the fuel may inherently have poor lubricity, poor cold-weather performance. The fuel may potentially have compatibility issues with fuel system elastomers.

If a renewable or alternative fuel fulfills the performance requirements described in Cat Fuel Specification, the latest version of "ASTM D975" or the latest version of "EN 590", then this fuel or a blend of this fuel (blended with appropriate distillate diesel fuel) can be used as a direct replacement of petroleum diesel in Cat engines.

Cat is following the development of renewable and alternative fuels and the respective fuel specifications to ensure successful application of these fuels in the engines. Information and guidelines will be published as the production of these fuels becomes established.

Aftermarket Fuel Additives

There are many different types of fuel additives that are available to use. Cat does not generally recommend the use of fuel additives.

In special circumstances, Cat recognizes the need for fuel additives. Fuel additives should be used with caution. The additive may not be compatible with the fuel. Some additives may precipitate. This action causes deposits in the fuel system. The deposits may cause seizure. Some additives may plug fuel filters. Some additives may be corrosive, and some additives may be harmful to the elastomers in the fuel system. Some additives may damage emission control systems. Some additives may raise fuel sulfur levels above the maximum allowed by the United States (U.S.) Environmental Protection Agency (EPA) or other regulatory agencies. Consult your fuel supplier for those circumstances when fuel additives are required. Your fuel supplier can make recommendations for additives to use and for the proper level of treatment.

Note: Metallic fuel additives can cause fuel system/injector fouling and after treatment device fouling. Cat discourages the use of metallic fuel additives in most applications. Metallic fuel additives should only be used in applications where the use is recommended by Cat.

Note: Diesel fuel additives/conditioners may not improve markedly poor diesel fuel properties enough to make the fuel acceptable for use.

Note: For best results, your fuel supplier should treat the fuel when additives are needed.

Cat Diesel Fuel Conditioner

Note: Cat Diesel Fuel Conditioner, part number 256-4968, is the only fuel additive available to the end user that is tested and approved by Cat for use in Cat diesel engines.

Cat Diesel Fuel Conditioner is a proprietary metal and ash free formulation that has been extensively tested for use with distillate diesel fuels for use in Cat diesel engines. Cat Diesel Fuel Conditioner helps address many of the challenges that various fuels worldwide present in regards to fuel life/stability, engine startability, injector deposits, fuel system life, and long-term engine performance.

Note: Diesel fuel additives/conditioners may not improve markedly poor diesel fuel properties enough to make the fuel acceptable for use.

Note: For maximum overall benefits, ask your fuel supplier to add Cat Diesel Fuel Conditioner at the recommended treat rate before fuel delivery. You may add Cat Diesel Fuel Conditioner at the recommended treat rate during the early weeks of fuel storage. Follow all applicable national, regional, and local laws, mandates, and regulations concerning the use of diesel fuel conditioners/additives.

Cat Diesel Fuel Conditioner is a proven high performance, multipurpose diesel fuel conditioner that is designed to improve:

- Fuel economy (through fuel system cleanup)
- Lubricity
- Oxidation stability
- Detergency/dispersancy
- Moisture dispersancy
- Corrosion protection
- Cetane (typically 2-3 cetane numbers)

Cat Diesel Fuel Conditioner has been validated through lab and field tests to improve/reduce diesel fuel consumption and emissions for typical fleets through fuel system/injector cleanup. The conditioner helps maintain new engine performance by keeping fuel systems clean. While fuel system/injector cleanup takes place over time, maintaining fuel system/injector cleanliness is an ongoing process.

Data indicates that average fuel economy improvements across typical fleets may be in the 2-3+ percentage range. Improvements may vary based on factors such as engine model, age and condition of the engine, and application.

Cat Diesel Fuel Conditioner also reduces the formation of gums, resins, and sludge, and disperses insoluble gums. The conditioner can dramatically improve fuel storage life, reduce fuel-related engine deposits and corrosion, and extend fuel filter life.

NOTICE

Use of Cat Diesel Fuel System Cleaner or Cat Diesel Fuel System Conditioner does not lessen the responsibility of the engine owner and/or responsibility of the fuel supplier to follow all industry standard maintenance practices for fuel storage and for fuel handling. Refer to the "General Fuel Information" article in this Special Publication for additional information. Additionally, use of Cat Diesel Fuel System Cleaner or Cat Diesel Fuel System Conditioner does NOT lessen the responsibility of the owner of the engine to use appropriate diesel fuel. Refer to the "Fuel Specifications" section in this Special Publication (Maintenance Section) for guidance.

Cat strongly recommends the use of Cat Diesel Fuel Conditioner with biodiesel and biodiesel blends. Cat Diesel Fuel Conditioner is suitable for use with biodiesel/biodiesel blends that meet Cat biodiesel recommendations and requirements. **Not all fuel additives are suitable for use with biodiesel/biodiesel blends.** Read and follow all applicable label usage instructions. Also, refer to this Special Publication, "Distillate Diesel Fuel" article and also refer to the "Biodiesel" article, which includes Cat biodiesel recommendations and requirements.

Cat Diesel Fuel Conditioner has proven to be compatible with existing and U.S. EPA 2007 on-highway certified diesel engine emission control catalysts and particulate filters.

Note: When used as directed, Cat Diesel Fuel Conditioner will not raise fuel sulfur levels measurably in the final fuel/additive blend. In the U.S. the current formulation of Cat Diesel Fuel Conditioner must be blended in at the recommended treat-rate at the fuel supplier/distributor level for use in on-highway or other applications where use of ULSD fuel is mandated (15 ppm or less fuel sulfur). Follow all applicable national, regional, and local laws, mandates, and regulations concerning the use of diesel fuel conditioners/additives.

NOTICE

When used as directed Cat Diesel Fuel Conditioner will not raise fuel sulfur levels measurably in the final fuel/additive blend. Follow all applicable national, regional, and local laws, mandates, and regulations concerning the use of diesel fuel conditioners/additives.

Cat Diesel Fuel System Cleaner

Note: Cat Diesel Fuel System Cleaner, part number 343-6210, is the only fuel system cleaner available to the end user that is tested and approved by Cat for use in Cat diesel engines.

Cat Diesel Fuel System Cleaner is a proven high performance detergent product designed for cleaning deposits that form in the fuel system. Deposits in the fuel system reduce system performance and can increase fuel consumption. Cat Diesel Fuel System Cleaner addresses the deposits formed due to the use of degraded diesel fuel, poor quality diesel fuel, and diesel fuel containing high quantities of high molecular weight compounds. Cat Diesel Fuel System Cleaner addresses deposits formed due to the use of biodiesel, biodiesel blends, and biodiesel that does not meet the appropriate quality specifications. Continued use of Cat Diesel Fuel System Cleaner is proven to inhibit the growth of new deposits.

Cat Diesel Fuel System Cleaner can be added directly to diesel fuel, biodiesel, or biodiesel blends. Cat Diesel Fuel System Cleaner is a United States Environmental Protection Agency registered fuel additive that can be used with Ultra Low Sulfur Diesel Fuel. In addition this cleaner is appropriate for use with other ultra low, low, and higher sulfur diesel fuels around the world.

Cat Diesel Fuel System Cleaner is a proven high performance cleaner that is designed to perform the following:

- Clean performance-robbing fuel system deposits
- Restore fuel economy losses resulting from injector deposits
- Restore power losses resulting from injector deposits
- Eliminate visible black exhaust smoke resulting from injector deposits
- Prevent the formation of new fuel-related deposits

For engines experiencing problems such as power loss, increased fuel consumption, or black smoke due to the presence of fuel-related deposits in fuel injectors, a high-strength cleaning cycle is recommended. Add one 0.946L (32 oz.) bottle of Cat Diesel Fuel System Cleaner per 250 L (65 gal) of fuel. One bottle corresponds to a treat rate of 0.4% by volume. Prior to refueling, pour Cat Diesel Fuel System Cleaner directly into the fuel tank, then refill with fuel. The refilling process should give satisfactory mixing of the cleaner. The cleaner will begin to be effective immediately. Testing has shown most deposits are cleaned and related issues are resolved after 30 hours of operating the engine on fuel with the cleaner. For maximum results, continue to use at this treat rate for up to 80 hours.

To prevent the return of fuel-related deposits, Cat Diesel Fuel System Cleaner, add the cleaner to the fuel at a 0.2% treat rate. In this case, one 0.946L (32 oz.) bottle will treat 500 L (130 gallons) of fuel. Cat Diesel Fuel System Cleaner can be used on an on-going basis with no adverse impact on engine or fuel system durability.

NOTICE

Use of Cat Diesel Fuel System Cleaner or Cat Diesel Fuel System Conditioner does not lessen the responsibility of the engine owner and/or responsibility of the fuel supplier to follow all industry standard maintenance practices for fuel storage and for fuel handling. Refer to the "General Fuel Information" article in this Special Publication for additional information. Additionally, use of Cat Diesel Fuel System Cleaner or Cat Diesel Fuel System Conditioner does NOT lessen the responsibility of the owner of the engine to use appropriate diesel fuel. Refer to the "Fuel Specifications" section in this Special Publication (Maintenance Section) for guidance.

Cat strongly recommends that Cat Diesel Fuel System Cleaner be used with biodiesel and biodiesel blends. Cat Diesel Fuel System Cleaner is suitable for use with biodiesel/biodiesel blends that meet Cat biodiesel recommendations and requirements. Not all fuel cleaners are suitable for use with biodiesel/biodiesel blends. Read and follow all applicable label usage instructions. Also, refer to this Special Publication, "Distillate Diesel Fuel", article and also refer to the "Biodiesel" article, which includes Cat biodiesel recommendations and requirements.

Cat Diesel Fuel System Cleaner has proven to be compatible with existing and U.S. EPA Tier 4 nonroad certified diesel engine emission control catalysts and particulate filters.

Note: When used as directed, Cat Diesel Fuel System Cleaner will not raise fuel sulfur levels measurably in the final fuel/additive blend. Follow all applicable national, regional, and local laws, mandates, and regulations concerning the use of diesel fuel conditioners/additives.

NOTICE

When used as directed Cat Diesel Fuel System Cleaner will not raise fuel sulfur levels measurably in the final fuel/additive blend. But, in the U.S., aftermarket fuel additives (retail consumer level versus bulk fuel additives used at the fuel supplier/distributor level) with more than 15 ppm sulfur are NOT allowed to be used in applications where ULSD usage is mandated (15 ppm or less fuel sulfur). Note that Cat Diesel Fuel System Cleaner contains less than 15 ppm of sulfur and is acceptable for use with ULSD fuel.

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Biodiesel

SMCS Code: 1280

NOTICE

These recommendations are subject to change without notice. Consult your local Cat dealer for the most up to date recommendations.

Biodiesel is a fuel that can be made from various renewable resources that include vegetable oils, animal fat, and waste cooking oil. Soybean oil and rapeseed oil are the primary vegetable oil sources. The raw oils or animal fats are chemically processed (esterified) to form a fatty acid methyl ester (referred to as FAME). The esterified product (FAME) is biodiesel fuel that can be used in compression ignition engines. Without the chemical processing referred to as esterification, the oils or fats are not suitable for use as fuel in compression ignition engines. To use any of the oils or fats listed above as fuel, the oil or fat must be esterified and the water and contaminants removed.

Fuel made of 100 percent FAME is referred to as B100 biodiesel or neat biodiesel.

Biodiesel can be blended with distillate diesel fuel. The blends can be used as fuel. The most commonly available biodiesel blends are B5, which is 5 percent biodiesel and 95 percent distillate diesel fuel, and B20, which is 20 percent biodiesel and 80 percent distillate diesel fuel. Note the percentages are volume-based.

U.S. distillate diesel fuel specification "ASTM D975-09a" includes up to B5 (5 percent) biodiesel. Currently, any diesel fuel in the U.S. may contain up to B5 biodiesel fuel.

European distillate diesel fuel specification "EN 590" includes up to B5 (5 percent) and in some regions up to B7 (7 percent) biodiesel. Any diesel fuel in Europe may contain up to B5 or in some regions up to B7 biodiesel fuel.

Note: The user of the engine has the responsibility of using the correct fuel that is recommended by the manufacturer. The fuel must be allowed by the U.S. EPA and other appropriate regulatory agencies.

Cat is not in a position to evaluate the many variations of biodiesel and the long-term effects on performance, durability, or compliance to emissions standards for Cat products.

Note: In order to align Cat recommendations with the latest revision of "ASTM D7467" specification for B6-B20 blends and to ensure that biodiesel fuel meets defined quality standards, Cat recommendations for acceptable biodiesel blend for most engines have been changed to B20. Details on the use of higher blends are given in this "Biodiesel" section of this Special Publication.

For Tier 4 applications in the U.S., the diesel fuel portion of the final blend must meet the requirements of S15 fuels (15 ppm sulfur) designations in the latest edition of "ASTM D975" specification. For Stage IIIB and later applications in EU, the diesel fuel portion of the final blend must meet the requirements for sulfur free (10 ppm sulfur) designation in the latest edition of "EN 590". The final blend must have 15 ppm sulfur.

NOTICE

In North America, the use of biodiesel from "BQ-9000" accredited producers and "BQ-9000" certified marketers is required. Refer to the "Recommendations" section for details.

NOTICE

Failures that result from the use of any fuel are not Caterpillar factory defects. Therefore, the cost of repair would NOT be covered by the Caterpillar warranty for materials and/or the warranty for workmanship.

Recommendations for the Use of Biodiesel in Cat Nonroad Engines

Refer to table 17 and 18 to the details provided in this section for biodiesel fuel requirements.

In order to be acceptable for blending, the biodiesel constituent must meet the requirements that are listed in "Cat Specification for Biodiesel Fuel" in this Special Publication, the latest edition of "ASTM D6751", and/or the latest edition of "EN14214".

Biodiesel blends of up to B5 must meet the requirements for the distillate diesel fuel that are listed in the "Cat Specification for Distillate Diesel Fuel for On-Highway Engines" in this Special Publication, the latest edition of "ASTM D975", and/or the latest edition of "EN 590".

Biodiesel blends of B6 to B20 must meet the requirements listed in the latest edition of "ASTM D7467" (B6 to B20) and must be of an API gravity of 30-45.

Distillate diesel fuels that meet the requirements of "Cat Specification for Distillate Diesel Fuel for On-Highway Engines" in this Special Publication, the "National Conference on Weights and Measures" (NCWM) Premium Diesel definition, the latest edition of "ASTM D975 S15" designation, and/or the latest edition of "EN 590", sulfur free designation. No. 1-D and No. 2-D are examples of fuels that are acceptable for creating biodiesel blends.

Table 16

Recommendations for biodiesel fuel application in Cat Off-Highway engines		
Production year/Tier/Stage	Engine model	Biodiesel acceptable blend levels
Tier 2 / Stage II or earlier Emissions Regulations	3003-3034, 3044, 3046, 3054, 3056, 3064, and 3066, 3054C (mechanical), 3054E (electronic) and 3056E (electronic). C0.5, C0.7, C1.1, C1.5, C1.6, C2.2, C3.4, C2.6, C3.3B. Certain C4.4 (S/N 44400001-04303), Certain C6.6 (S/N CE600001-14623 (Machines) and S/N 66600001-09015 (Industrial))	Up to B5 ⁽¹⁾
Tier 4 Interim / Stage IIIa (without aftertreatment)	C1.8, C2.4, C3.3B	
Tier 4 Interim / Stage IIIb (with aftertreatment devices)	C3.8, C3.4	
Tier 4 Interim / Stage IIIb and beyond (with aftertreatment devices)	ACERT engines: C4.4, C6.6, C7.1, C9.3, C13, C15, C18, C27, and C32	Up to B20
All years post Tier 2/Stage II	C0.5 through C2.2 ⁽²⁾ Certain C4.4 ACERT (S/N C4E05524-Up (Machines) and 44404304 -Up (Industrial)), C4.4 (Mechanical), C6.4, and certain C6.6 ACERT (S/N CE614624-Up (Machines) and 66609016-Up (Industrial))	Up to B20 (For use of higher blend levels up to B100, consult your Cat dealer)
All years	3114, 3116, 3126, 3176, 3196, 3208, 3306 3406, 3408, 3412, 3456, 3406E, 3408E, 3412E, 3500 Series, and 3600 Series C-9, C10, C-12, C-15, C-16, C-18, C280 Series, CM20, CM25, and CM32 ACERT engines ⁽¹⁾ sure C7, C9, C9.3, C11, C13, C15, C18, C27, C32, and C175	

(1) Up to B7 can be used in these engines. B7 has to be per Cat distillate diesel fuel specification, "ASTM D975 or EN590".

(2) Models without aftertreatment only

Table 17

Fuel Recommendations for Cat Nonroad Engines		
Biodiesel Blend Stock	Final Blend	Distillate Diesel Fuel used for blending
Cat biodiesel specification, ⁽¹⁾ "ASTM D6751" or "EN14214"	B5: Cat distillate diesel fuel specification, ⁽²⁾ "ASTM D975" or "EN590"	Cat distillate diesel fuel specification, "ASTM D975" or "EN590"
	B20: "ASTM D7467" and "API" gravity 30-45	

(1) Refer to Table 19 in the Biodiesel section of this Special Publication.

(2) Refer to "Cat Specification for Distillate Diesel Fuel for On-Highway Engines" in the Fuel section of this Special Publication.

Note: For Tier 4 certified/ Stage IIIB and newer engine models that are equipped with aftertreatment devices, use only the biodiesel blend levels that are recommended in "Recommendations for biodiesel fuel application in Cat Nonroad Engines" in this Special Publication, table 16. Use of biodiesel blend levels higher than the recommendations provided in table 16 can adversely affect engine and aftertreatment components due to contaminants. The repair of any engine or aftertreatment components due to such contamination or due to other biodiesel impacts would not be covered under the Cat warranty. Refer to "Additional Maintenance Requirements" topic in this Special Publication, "Biodiesel" article.

Note: For 2006 and older engine models, for use of blends of biodiesel above B20 (20 percent), refer to "Guidelines and potential impacts associated with the use of biodiesel and biodiesel blends" table 18 in this Special Publication for the guidelines and impacts of using high biodiesel blends. Consult your Cat dealer for guidance. Use the Cat S-O-S Services oil analysis program when biodiesel or blends of biodiesel that are B20 (20 percent) or above are used.

Either "ASTM D7371" - "Test Method for Determination of Biodiesel (Fatty Acid Methyl Esters) Content in Diesel Fuel Oil Using Mid Infrared Spectroscopy (FTIR-ATR-PLS Method)" or "EN 14078" - "Liquid Petroleum Products - Determination of fatty acid methyl esters (FAME) in middle distillates - Infrared spectroscopy method" can be used for determining the volume percent biodiesel in a biodiesel blend.

For applications running biodiesel or biodiesel blends, the recommendation is to use either Cat Diesel Fuel System Cleaner (Part number 343-6210) or Cat Diesel Fuel Conditioner (Part number 256-4968). Cat Diesel Fuel System Cleaner, used as needed or on an on-going basis, is most effective at cleaning and preventing the formation of fuel-related deposits. Cat Diesel Fuel Conditioner can be used to improve fuel stability and can help prevent the formation of fuel-related deposits.

Additional maintenance requirements

When biodiesel fuel is used, crank case oil and aftertreatment systems may be influenced. This influence is due to the chemical composition and characteristics of biodiesel fuel such as density and volatility. Chemical contaminants can be present in this fuel, such as phosphorous, alkali, and alkaline metals (sodium, potassium, calcium, and magnesium).

- Crankcase oil fuel dilution can be higher when biodiesel and/or biodiesel blends are used. This increased level of fuel dilution when using biodiesel and/or biodiesel blends is related to the typically lower volatility of biodiesel. In-cylinder emissions control strategies utilized in many of the latest engine designs may lead to a higher level of biodiesel concentration in the sump. The long-term effect of biodiesel concentration in crankcase oil is currently unknown. **The use of Cat S-O-S Services oil analysis is recommended when up to B20 (20 percent) and lower biodiesel blends are used. Analysis is required when using biodiesel/biodiesel blends that are B20 or above.** When requesting oil analysis, be sure to note the level of biodiesel being used (B5, B20, and so on).
- Biodiesel fuel contains metal contaminants (phosphorous, sodium, potassium, calcium, and/or magnesium) that form ash products upon combustion in the diesel engine. The ash can affect the life and performance of aftertreatment emissions control devices and can accumulate in Diesel Particulate Filters (DPF). The ash accumulation may cause the need for more frequent ash service intervals and/or cause loss of performance.

Fuel System Deposits

Biodiesel and biodiesel blends are known to cause an increase in fuel system deposits, most significant of which are deposits within the fuel injector. These deposits can cause a loss in power due to restricted or modified fuel injection or cause other functional issues associated with these deposits. Cat Diesel Fuel System Cleaner (part number 343-6210) is most effective in cleaning and preventing the formation of deposits. Cat Diesel Fuel Conditioner (part number 256-4968) helps to limit deposit issues by improving the stability of biodiesel and biodiesel blends. The production of new deposits is also inhibited. **Therefore, the use of Cat Diesel Fuel System Cleaner and/or Cat Diesel Fuel Conditioner is recommended when running any biodiesel or biodiesel blends.** Refer to this Special Publication, "Distillate Diesel Fuel", article, "Cat Diesel Fuel Conditioner" and "Cat Diesel Fuel System Cleaner" topics in this Special Publication, "Distillate Diesel Fuel" for additional information.

Consult your Cat dealer for availability of Cat Diesel Fuel System Cleaner and Cat Diesel Fuel Conditioner.

Guidelines

Biodiesel that meets the requirements that are listed in the "Cat Specification for Biodiesel Fuel", the latest edition of "ASTM D6751", or the latest edition of "EN 14214" is not expected to pose major problems when blended with an acceptable distillate diesel fuel at the maximum stated percentages. However, the following recommendations should be followed:

Note: For these recommendations, the cautions, guidelines, and recommendations applicable to biodiesel (B100) are also applicable to biodiesel blends (B2, B5, B20, and so on). The impacts of biodiesel blends higher than B20 are, in general, more severe than the impacts of biodiesel blends of B20 or lower. Refer to Table 18 of this Biodiesel section for more details.

Note: Fuel storage tanks need to be cleaned thoroughly before converting to biodiesel/biodiesel blends. Conversion to biodiesel/biodiesel blends can loosen fuel system and fuel storage tank deposits. All tank filters and engine filters must shorten the change intervals for an extended time in order to allow for this cleaning effect.

In North America, the use of biodiesel from "BQ-9000" accredited producers and marketers is required. Look for the "BQ-9000" biodiesel quality accreditation program certification logo that is available to distributors that meet the requirements of "BQ-9000". For more information on the "BQ-9000" program, go to "www.BQ-9000.org".

In other areas of the world, the use of biodiesel that is "BQ-9000" accredited and certified, or that is accredited and certified by a comparable biodiesel quality body to meet similar biodiesel quality control standards, is required.

Information provided in this table refers to biodiesel and biodiesel blends that fully comply with the appropriate specifications as described in the "Biodiesel" section of this Special Publication and to handling and maintenance procedures that follow recommended guidelines.

Table 18

Risks and Guidelines associated with the use of biodiesel and biodiesel blends ⁽¹⁾				
Paragraph reference	Risk/Recommendation	B5	B6-B20	B21-B100
1	Risk of reduction of oil change interval	Negligible	Low	High
2	Risk of fuel filters compatibility	Negligible	Low	Medium
3	Risk of reduction of fuel filter change interval	Negligible	Medium	High
4	Bulk filtration of biodiesel	≤4 microns absolute	≤4 microns absolute	≤4 microns absolute
5	Energy content of biodiesel	Similar to Diesel	Minor loss of 1-2 percent	Detectable loss of 5-8 percent
6	Compatibility with elastomers	Low	Low-Medium	High
7	Risk of low ambient temperature problems for both storage and operation.	Medium	Medium-High	High
8	Feedstock impact	Medium	Medium	High
9	Risk of oxidation stability and injector deposits	Low	Medium	High
10	Oxidation stability-Duration of storage	Similar to Diesel fuel	8 months ⁽²⁾	4 months ⁽³⁾
11	Use in engines with limited operational time	Maximum allowed	Unacceptable	Unacceptable
12	Risk of microbial contamination and growth	Medium	High	High
13	Need for water removal	Medium	High	High
14	Oil-side seal incompatibility	Negligible	Medium	High
15	Metal incompatibility	Negligible	Low	High

(1) Refer to the paragraph reference number for details of each listed Risk/Recommendation.

(2) Testing of B20 blends is recommended at 4 months of storage and on a monthly basis thereafter. Tests should include oxidation, acid number, viscosity, and sediments.

(3) B100 stored for over 2 months should be tested every 2 weeks to ensure that the fuel is not degraded. Tests should include oxidation, acid number, viscosity, and sediments. The use of appropriate additives is required if B100 is stored more than 4 months. Consult your fuel supplier for more information. In addition, B100 should be stored at temperatures of 3 degrees C to 6 degrees C (5 degrees F to 10 degrees F) above the cloud point.

The following are the paragraph reference numbers:

1. The oil change interval can be negatively affected by the use of biodiesel. Use S·O·S Services oil analysis in order to monitor the condition of the engine oil. S·O·S Services oil analysis will also help determine the oil change interval that is optimum.
2. Confirm with the filter manufacturer that the fuel filter/filters to be used are compatible with biodiesel. Fuel water separators are preferred when biodiesel is used.
3. Conversion to biodiesel can loosen fuel system deposits. Fuel filter change intervals must be shortened for an extended time in order to allow for this cleaning effect. Filter change interval of 50 hours or less is recommended following the initial conversion to B20 biodiesel blend.
4. Filter biodiesel and biodiesel blends through a fuel filter with a rating of four microns(c) absolute or less. Filters should be located on the device that dispenses the fuel to the fuel tank for the engine. Filters should be located on the device that dispenses fuel from the bulk storage tank. Series filtration is recommended.

Note: Cat fuel filters and Cat fuel water separators are compatible with biodiesel fuel.

5. In a comparison of distillate fuels to biodiesel, neat biodiesel (B100) typically provides less energy per gallon by 5 percent to 8 percent. Do NOT attempt to change the engine rating in order to compensate for the power loss. Engine problems may occur when the engine is converted back to 100 percent distillate diesel fuel. Any adjustments to the engine to compensate for the power loss may result in violation of emissions regulations such as the U.S. EPA anti-tampering provisions.
6. Compatibility of the elastomers with biodiesel is currently being monitored. The condition of seals and hoses should be monitored regularly. Biodiesel may soften, degrade, or leak from some types of elastomers used in seals and hoses. The higher biodiesel blend has a greater the risk of elastomer-related issues.
 - a. In general, Cat engines built early to mid 90s use Viton seals and Viton O-rings in the fuel system. Viton is compatible with biodiesel.
 - b. Nitrile hoses typically used in some fuel transfer lines are not compatible with biodiesel. Monitor the condition of the hoses and confirm with the hose manufacturer that the hoses are compatible with the biodiesel blend used. If necessary, replace with hoses of compatible materials.
7. Biodiesel may pose low ambient temperature problems for both storage and operation. At low ambient temperatures, biodiesel fuel may need to be stored in a heated building or a heated storage tank. The fuel system may require heated fuel lines, filters, and tanks. Filters may plug and fuel in the tank may solidify at low ambient temperatures if precautions are not taken. Consult your biodiesel supplier for assistance in the blending and attaining of the proper cloud point for the fuel.

Note: The performance of cold flow improvers can be reduced in the presence of biodiesel fuel. Consult the fuel supplier for appropriate cold flow improvers if needed.
8. Biodiesel can be produced using various renewable sources. The source used can affect product performance. Two of the fuel characteristics affected are cold flow and oxidation stability. Cold flow affects filter plugging and oxidation stability affects deposit formation and biodiesel fuel storage duration and life. Consult your fuel supplier for guidance.
9. Biodiesel has poor oxidation stability, which may accelerate fuel oxidation in the fuel system. Engines with an electronic fuel system operate at higher temperatures, which may accelerate fuel oxidation. Oxidized fuel can form deposits in fuel injection systems and in fuel systems in general. Refer to this Special Publication, "Distillate Diesel Fuel" article, "Aftermarket Fuel Additives", "Cat Diesel Fuel Conditioner", and "Cat Diesel Fuel System Cleaner" topics for information concerning oxidation stability and other fuel additives.
10. Poor oxidation stability of biodiesel can result in long-term storage problems. Biodiesel should be used within a limited time from production. In order to ensure appropriate storage duration, testing of the stored biodiesel is recommended. Tests should include oxidation, acid number, viscosity, and sediments. Tests should be conducted periodically to ensure that biodiesel is per specification. Antioxidants are recommended to improve stability of biodiesel. Cat Diesel Fuel Conditioner, part number 256-4968, or appropriate commercial additives are recommended. Consult your fuel supplier for more information.
 - a. B20 biodiesel blend can generally be stored up to 8 months. Testing of B20 blends is recommended at 4 months of storage and on a monthly basis thereafter to ensure that the fuel has not degraded.
 - b. B100 biodiesel can generally be stored up to 4 months. Testing of B100 is recommended at 2 months of storage and every two weeks thereafter to ensure that the fuel has not degraded. The use of appropriate additives is required if B100 is stored more than 4 months. Consult your fuel supplier for more information.
 - c. B100 should be stored at temperatures of 3 degrees C to 6 degrees C (5 degrees F to 10 degrees F) above the cloud point.
11. Due to poor oxidation stability and other potential issues, Cat recommends that engines with limited operational time (such as seasonal use or standby power generation) either not use biodiesel/biodiesel blends or, while accepting some risk, limit biodiesel to a maximum of B5. Examples of applications that should limit the use of biodiesel are the following: Standby Generator sets and certain emergency vehicles. For more information, refer to the "Seasonal Operation" section.

- a. Addition of Cat Diesel Fuel Conditioner, part number 256-4968, or an appropriate commercial additive containing antioxidants/oxidation stability improvers, is recommended for standby generator sets and emergency vehicles using biodiesel/biodiesel blends. The conditioner should be added when the engine is fueled or as early as possible when the fuel is delivered and stored. Preferably, the conditioner or additive should be added as soon as possible after the fuel is produced.

- b. For standby generator sets and emergency vehicles that use biodiesel, sample the fuel in the engine tank monthly. Test the fuel for acid number and oxidation stability. If the test results show that the fuel is degraded and that the fuel is not per the appropriate specifications (provided in Table 19 in this "Biodiesel" section), drain the tank, flush the engine by running using high-quality fuel. Repeat the process until the system is clean. Refill with high-quality fuel following the recommendations provided in this "Fuel" section

- c. For standby generator sets and emergency vehicles that use biodiesel, Cat recommends that the fuel oxidation stability is 10 hours or more per "EN 14112" test method.

12. Biodiesel is an excellent medium for microbial contamination and growth. Microbial contamination and growth can cause corrosion in the fuel system and premature plugging of the fuel filter. Consult your supplier of fuel and additive for assistance in selecting appropriate anti-microbial additives.

13. Care must be taken in order to remove water from fuel tanks. Water accelerates microbial contamination and growth. When biodiesel is compared to distillate fuels, water is naturally more likely to exist in the biodiesel.

14. Biodiesel dilution of engine oil may result in oil side leaks due to incompatibility of the seals that are typically used on the oil side. Liner seals and oil cooler seals may be affected by biodiesel dilution. Monitor the condition of the oil side seals and consult your Cat dealer for appropriate replacement if needed.

15. Biodiesel is not compatible with some metals. Biodiesel of blends higher than B20 will oxidize and form sediments upon long-term contact with lead, zinc, tin, copper, and copper alloys such as brass and bronze. Consult your dealer for more information.

Note: The use of biodiesel at a B2 level improves the lubricity of the final blend by an estimated 66 percent. Increasing the blend level higher than B2 does not improve the lubricity any further.

Seasonal Operation

Cat recommends that seasonally operated engines have the fuel systems, including fuel tanks, flushed with conventional diesel fuel before prolonged shutdown periods. Applications that should seasonally flush the fuel system include school buses (U.S.) and farm machinery.

Perform the following process before shutting down the engine for prolonged periods:

1. Operate the engine until the fuel level in the tank is low.
2. Refill the fuel tank with high quality conventional distillate diesel fuel.
3. Repeat steps 1 and 2 a minimum of two times before the engine is shut down for prolonged periods.

If distillate fuel is not available to operate the engine as described above, while accepting some risk, limit biodiesel to a maximum of B5. Follow the recommendations provided in this section and the guidelines given below to reduce the risk:

- Addition of Cat Diesel Fuel Conditioner, part number 256-4968, or an appropriate commercial additive containing antioxidants/oxidation stability improvers, is recommended prior to engine shutdown for prolonged periods. The conditioner should be added when the engine is fueled. Preferably, the conditioner is added to the fuel as soon as possible after the fuel production.
- Addition of Cat Diesel Fuel System Cleaner, part number 343-6210, or an appropriate commercial cleaner is recommended when the engine is first operated after the prolonged shutdown period and preferably for a total of two tanks of fuel. Follow the recommendations provided in the Cat Diesel Fuel System Cleaner section in the "Fuel" article in this Special Publication.

Consult your Cat dealer for the availability of Cat Diesel Fuel Conditioner and Cat Diesel Fuel System Cleaner.

Biodiesel Specification

Biodiesel fuel used that is used for blending must meet the requirements in the following table.

The final blend of biodiesel as used in the engine must meet the requirements that are stated in table 17 this "Biodiesel" article.

B100 intended for blending into diesel fuel that is expected to give satisfactory vehicle performance at fuel temperatures at or below -12°C (10.4°F) shall comply with a cold soak filterability limit of 200 seconds maximum. Passing the "ASTM D6751" 200 seconds Cold Soak Filterability test limit does not guarantee cold performance for all biodiesel blends at all possible fuel temperatures, but biodiesel that fails this Cold Soak Filterability test requirement will produce biodiesel blends that will likely plug fuel filters when fuel temperatures are below -12°C (10.4°F).

Table 19

Cat Specification for Biodiesel Fuel				
Property	Test Method	Test Method	Units	Limits
	United States	International	Specific Properties of Fuel	
Density at 15°C	"ASTM D1298"	"ISO 3675"	g/cm ³	0.86-0.90
Viscosity at 40°C	"ASTM D445"	"ISO 3104"	mm ² /s (cSt)	1.9-6.0
Flash Point	"ASTM D93"	"ISO 3679"	°C	93 minimum
Pour Point - Summer - Winter	"ASTM D97"	"ISO 3016"	°C	6 °C (10 °F) minimum below ambient temperature
Cloud Point	"ASTM D2500"		°C	Report
Sulfur Content	"ASTM D5453"	"ISO 20846" "ISO 20884"	percent weight	0.0015 maximum
Distillation - 10 percent Evaporation - 90 percent Evaporation	"ASTM D1160"		°C	To Be Determined 360
Carbon Residue, Conradson (CCR)	"ASTM D4530"	"ISO 10370"	percent weight	0.05 maximum
Cetane Number	"ASTM D613"	"ISO 5165"		45 minimum
Sulfated Ash	"ASTM D874"	"ISO 3987"	percent weight	0.02 maximum
Water/Sediment Content	"ASTM D2709"	"ISO 12937"	percent volume	0.05 maximum
Copper Corrosion	"ASTM D130"	"ISO 2160"		No. 1
Oxidation Stability	"EN 14112"	"EN 14112"	hours	3 minimum
Esterification	"EN 14103"	"EN 14103"	percent volume	97.5 minimum
Acid Value	"ASTM D664"	"EN 14104"	mg KOH/g	0.5 maximum
Methanol Content	"EN 14110"	"EN 14110"	percent weight	0.2 maximum
Monoglycerides	"ASTM D6584"	"EN 14105"	percent weight	0.8 maximum
Diglycerides	"ASTM D6584"	"EN 14105"	percent weight	0.2 maximum
Triglycerides	"ASTM D6584"	"EN 14105"	percent weight	0.2 maximum
Free Glycerin	"ASTM D6584"	"EN 14105"	percent weight	0.02 maximum
Total Glycerin	"ASTM D6584"	"EN 14105"	percent weight	0.240 maximum
Phosphorus Content	"ASTM D4951"	"EN 14107"	percent weight	0.001
Calcium and Magnesium combined	"EN 14538"	"EN 14538"	ppm	5 maximum
Sodium and Potassium combined	"EN 14538"	"EN 14538"	ppm	5 maximum
Cold Soak Filterability	"ASTM D7501"	--	seconds	360 maximum
Cleanliness	"ASTM D7619"	"ISO 4406"	--	(1)

(1) Recommended cleanliness level for fuel as dispensed into machine or engine fuel tank is "ISO 18/16/13" or cleaner per "ISO 4406" or "ASTM D7619". Refer to the "Contamination Control" section in this Special Publication.

Note: Fuels that meet the most current revision level of "ASTM D6751" or "EN 14214" may be used for blending with an acceptable distillate fuel. The conditions, recommendations, and limits that are noted in this Biodiesel section apply.

Referenced Documents

Refer to the "Reference Material - Fuel" section of this Special Publication for the reference material for the information in this section.

Cooling System Specifications

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General Coolant Information

SMCS Code: 1350; 1395

WARNING

The cooling system operates under pressure which is controlled by the radiator pressure cap. Removing the cap while the system is hot may allow the escape of hot coolant and steam, causing serious burns.

Before you remove the radiator cap, allow the system to cool. Use a thick cloth and turn the radiator cap slowly to the first stop to allow pressure to escape before fully removing the cap.

Avoid contact with coolant.

NOTICE

Every attempt is made to provide accurate, up-to-date information. By the use of this document, you agree that Caterpillar Inc. is not responsible for errors or omissions.

The information that is provided is the latest recommendations for the Cat diesel engines that are covered by this Special Publication. This information supersedes all previous recommendations which have been published for the Cat diesel engines that are covered by this Special Publication. Special fluids may be required for some engines. Continue to use these special products. Refer to the applicable Operation and Maintenance Manual.

This publication is a supplement to the Operation and Maintenance Manual. This publication does not replace the engine Operation and Maintenance Manual.

NOTICE

These recommendations are subject to change without notice. Consult your local Cat dealer for the most up to date recommendations.

NOTICE

In order to avoid potential damage to your Cat machine and/or Cat engine, only purchase Cat fluids and Cat filters through your Cat dealer or Cat authorized outlets. For a list of authorized Cat parts outlets in your area, consult your Cat dealer.

If you purchase what appear to be Cat fluids and/or Cat filters through other outlets/sources, you are at a very high risk of purchasing counterfeit ("look-alike") products.

Counterfeit or "look-alike" products may visually appear the same as the original Cat product, but the product performance and internal quality will typically be very low.

Counterfeit or "look-alike" products have a very high likelihood of causing and/or allowing engine and/or machine compartment damage.

NOTICE

Commercial products that make generic claims of meeting "Cat" requirements without listing the specific Cat recommendations and requirements that are met may not provide acceptable performance. Commercial products may cause reduced engine and/or machine fluid compartment life. Refer to this Special Publication and refer to product specific Operation and Maintenance Manual for Cat fluids recommendations and requirements.

NOTICE

Never add coolant to an overheated engine. Engine damage could result. Allow the engine to cool first.

NOTICE

If the engine is to be stored in, or shipped to an area with below freezing temperatures, the cooling system must be either protected to the lowest outside temperature or drained completely in order to prevent damage caused by freezing coolant.

NOTICE

Never operate an engine without water temperature regulators in the cooling system. Water temperature regulators help to maintain the engine coolant at the proper operating temperature. Cooling system problems can develop without water temperature regulators.

If you operate the engine without the regulator, some coolant bypasses the radiator. This may cause overheating.

Note: Refer to the specific engine Operation and Maintenance Manual, "Maintenance Interval Schedule" for the correct interval for the replacement of the thermostat.

Refer to Special Instruction, SEBD0518, "Know Your Cooling System" for more detailed information.

Many engine failures are related to the cooling system. The following problems are related to cooling system failures:

- Overheating
- Leakage of the water pump
- Plugged radiators or heat exchangers
- Pitting of the cylinder liners

These failures can be avoided with proper cooling system maintenance. Cooling system maintenance is as important as maintenance of the fuel system and the lubrication system. Quality of the coolant is as important as the quality of the fuel and the lubricating oil.

A coolant that is ready to use in the engine can also be referred to as "finished coolant". A finished coolant is a coolant that has been diluted with appropriate amount of acceptable quality water.

Coolant is normally composed of the following elements:

- water
- additives
- glycol
- Embitterment: in coolants containing ethylene glycol to make the coolant taste bad.

Technical information for each of the coolant elements is provided in this Special Publication.

Water

NOTICE

Never use water alone as a coolant. Water alone is corrosive at engine operating temperatures. In addition, water alone does not provide adequate protection against boiling or freezing.

Note: In glycol-based coolants, Cat strongly recommends a minimum of 30 percent glycol in diesel engine cooling systems, with a minimum of 50 percent glycol recommended. Use only glycol-based coolants that meet one or more of the coolant specifications that are defined as preferred or acceptable in this Special Publication and that also comply with any additional requirements that are stated in this Special Publication (that is, chemical composition, the use of SCA, the use of Extender). Refer to the Operation and Maintenance Manual for your engine for any exceptions.

NOTICE

All Cat engines that are equipped with a Cat NOx Reduction System require a minimum of 50 percent glycol to help prevent cavitation damage and boiling of the engine coolant. These engines include Tier 4 engines.

Table 20

Special Requirements	
Cat C7-C32 Marine Engines with heat exchangers	Minimum of 30% glycol is required. 50% Glycol is recommended. Water alone or water with SCA or with ELI is NOT allowed.
Cat diesel engines equipped with air-to-air aftercooling (ATAAC)	
Cat 3618 engine model	Water-ELI is recommended. Water-SCA is acceptable. Glycol-based coolants are NOT allowed.
Cat 3500C engine model Marine EPA Tier 3 capable engines (heat exchanger cooled and keel cooled configurations)	Maximum of 20% glycol is allowed in the aftercooler circuit. ⁽¹⁾ (not applicable to the jacket water circuit, which is capable of 50% glycol)

(1) For freezing protection of -5° C (23° F) temperatures and lower, consult your Cat dealer for guidance.

C7-C32 heat exchanger cooled marine engines require a minimum of 30 percent glycol to prevent cavitation of cooling system components, with a minimum of 50 percent glycol recommended.

Water in the water/glycol coolants is more effective than glycol alone in transferring heat.

Distilled water or deionized water is recommended to add to glycol or to water based coolants in engine cooling systems.

DO NOT use the following types of water in cooling systems: hard water, softened water that has been conditioned with salt, and sea water.

If distilled water or deionized water is not available, use water that meets or exceeds the minimum acceptable water requirements that are listed in Table 21.

Table 21

Cat Minimum Acceptable Water Requirements		
Property	Maximum Limit	ASTM Test
Chloride (Cl)	40 mg/L (2.4 grains/US gal)	"D512", "D4327"
Sulfate (SO ₄)	100 mg/L (5.9 grains/US gal)	"D516" "D4327"
Total Hardness	170 mg/L (10 grains/US gal)	"D1126"
Total Solids	340 mg/L (20 grains/US gal)	"D1888" "Federal Method 2504B" ⁽¹⁾
Acidity	pH of 5.5 to 9.0	"D1293"

(1) Total dissolved solids dried at 103° C (217° F) - 105° C (221° F), "Standard Method for the Examination of Water and Wastewater", "American Public Health Association", "www.apha.org", "www.aphabookstore.org", (888) 320-APHA.

For a water analysis, consult one of the following sources:

- Cat dealer

- Local water utility company
- Agricultural agent
- Independent laboratory

Periodic analysis of water that is used to add to the coolant is recommended. Water quality can be affected by various factors including malfunctioning purification equipment, earthquakes, and droughts.

Additives

Additives help to protect the metal surfaces of the cooling system and can improve coolant performance. A lack of coolant additives, insufficient amounts of additives, or improper additives for the application can cause the following conditions to occur:

- Corrosion
- Formation of mineral deposits
- Rust
- Scale
- Pitting and erosion from cavitation of the cylinder liner
- Foaming of the coolant

Many additives are depleted during engine operation. These additives must be replaced periodically. Additives that can be added:

- ELC Extender to Cat ELC (Extended Life Coolant)
- ELC Extender to Cat ELI (Extended Life Inhibitor)
- Cat SCA (Supplemental Coolant Additive) to Cat DEAC (Diesel Engine Antifreeze/Coolant)
- Cat SCA to Cat SCA in water finished coolant

Additives must be added at the proper concentration. Overconcentration of additives can cause the inhibitors to drop out-of-solution. The deposits can enable the following problems to occur:

- Formation of gel compounds
- Reduction of heat transfer
- Leakage of the water pump seal
- Plugging of radiators, coolers, and small passages

Glycol

Glycol in the coolant helps to provide protection against the following conditions:

- Boiling
- Freezing
- Water pump cavitation (ATAAC equipped engines)

For optimum performance, Cat recommends a 50 percent by volume of glycol in the finished coolant (also referred to as 1:1 mixture).

Note: Use a mixture that will provide protection against the lowest ambient temperature.

Most conventional heavy-duty coolant/antifreezes use ethylene glycol. Propylene glycol may also be used. In a 50 percent by volume of glycol in the finished coolant, ethylene and propylene glycol provide similar protection against freezing and boiling. Refer to tables 22 and 23.

Table 22

Ethylene Glycol Concentration		
Concentration	Freeze Protection	Boil Protection ⁽¹⁾
50 Percent	-37 °C (-34 °F)	106 °C (223 °F)
60 Percent	-52 °C (-62 °F)	111 °C (232 °F)

⁽¹⁾ Boiling protection is increased with the use of a pressurized radiator.

Do not use propylene glycol in concentrations that exceed 50 percent glycol because of the reduced heat transfer capability. Use ethylene glycol in conditions that require additional protection against boiling or freezing. Do not use ethylene glycol in concentrations that exceed 60 percent glycol.

Table 23

Propylene Glycol Concentration		
Concentration	Freeze Protection	Boil Protection ⁽¹⁾
50 Percent	-32 °C (-26 °F)	106 °C (223 °F)

⁽¹⁾ Boiling protection is increased with the use of a pressurized radiator.

Propylene glycol coolant that is used in the cooling systems for Cat diesel engines must meet ASTM D6210-06, "Fully-Formulated Glycol-Based Engine Coolant for Heavy-Duty Engines". When propylene glycol coolant is used in heavy-duty diesel engines, a regular addition of SCA is required for protection against liner cavitation. Consult your Cat dealer for additional information.

Ethylene or propylene glycols used in cooling systems for Cat diesel engines must meet ASTM E1177-06, "Standard Specification for Engine Coolant Grade Glycol".

Testing the Concentration of Glycol

To check the concentration of glycol, use the 245-5829 Coolant/Battery Tester/Refractometer or 360-0774 refractometer. The tester can be used with ethylene or propylene glycol.

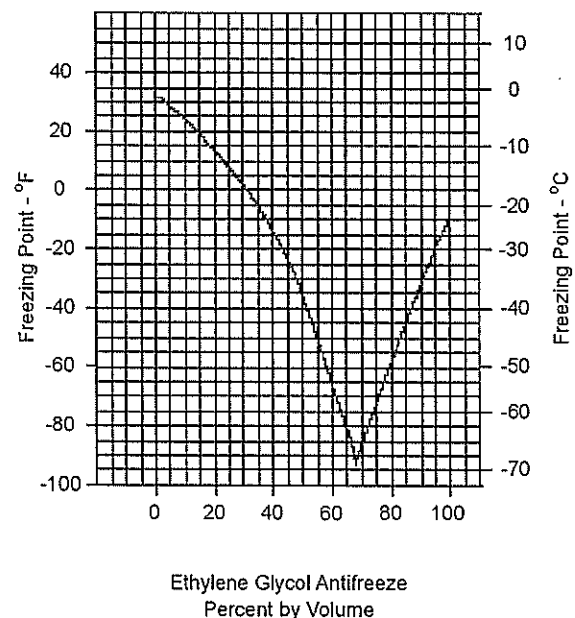


Illustration 3

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Approximate curve of the freezing point for a typical ethylene glycol solution.

Table 24

Freeze Protection for Antifreeze Concentrations ⁽¹⁾	
Protection to:	Concentration
-15 °C (5 °F)	30% glycol 70% water
-24 °C (-12 °F)	40% glycol 60% water
-37 °C (-34 °F)	50% glycol 50% water
-52 °C (-62 °F)	60% glycol 40% water

(1) Ethylene glycol-based antifreeze.

Alternative products that are used to protect from boiling or freezing of the engine coolant include:

- "1,3 propandiol" (PDO)
- glycerin
- mixtures of these alternative products with glycol

At the time of publication of this document, there currently exists no ASTM, "specifications" for coolants using these chemicals. **Until specifications are published and then evaluated by Cat, use of PDO and glycerin or glycerin/glycol coolants are not recommended in Cat cooling systems.**

Embitterment

Ethylene glycol is a toxic chemical with a naturally sweet taste. In order to avoid accidental excessive ingestion by humans or animals, coolants may contain embittering agents that make the coolant taste bad. **All Cat glycol containing coolants (Cat ELC, Cat DEAC, and Cat NGE) are embittered.** Embittering agents have no beneficial or detrimental effect on coolant performance or characteristics.

Coolant Terminology

Extended Life Coolant (ELC) – A coolant that relies largely on organic inhibitors for corrosion and cavitation protection. Carboxylate is an example of organic corrosion and cavitation inhibitors. Cat ELC and Cat ELI in water are extended life coolants that also include nitrites and molybdates for increased cavitation protection.

- Commercial extended life coolants containing silicate do not meet the additional requirements set in this Special Publication for coolants claiming to meet Cat EC-1 specification.
- Do not use commercial extended life coolants with more than 125 ppm silicon (present in the coolant in the form of silicate)

- Extended life coolants that meet "ASTM D4985-05" or "ASTM D6210-06" may be used at the recommended maximum coolant service life intervals stated in this Special Publication for coolants that meet the ASTM specifications.

Conventional coolant – A coolant that relies largely on inorganic inhibitors for corrosion and cavitation protection. Silicates and nitrites are examples of inorganic inhibitors. Conventional coolants are also referred to as heavy-duty coolants, heavy-duty fully formulated coolants, or traditional coolants. In order to be used in most Cat cooling systems, conventional coolants must meet "ASTM D4985-05" or "ASTM D6210-06". Cat DEAC and Cat SCA in water (also referred to as SCA/Water coolant) are conventional coolants

Supplemental Coolant Additive (SCA) – SCA is a general term for a concentrated inorganic inhibitor package. SCA is used for three different purposes:

- to precharge a new conventional coolant that is not fully Formulated. Cat DEAC is fully formulated and does not require SCA
- to provide corrosion protection in water/SCA cooling systems
- to recharge an in service conventional coolant on a maintenance basis to maintain proper inhibitor levels

Extender – An inhibitor package that is added to extended life coolants, to recharge an in-service coolant. Extenders, typically, only should be added at one half the service life of the coolant.

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Coolant Recommendations (General Maintenance)

SMCS Code: 1350; 1352; 1395

The finished coolants that are recommended or acceptable for use in Cat diesel engines are given in Table 25 below:

Table 25

Recommendations for Finished Coolants for use in Cat engines				
Coolant Type	Recommendations	Product	Service hours ⁽¹⁾⁽²⁾	Required Maintenance
Cat ELC, Cat ELI, or commercial coolant that meets Cat EC-1	Preferred	Cat ELC	12000 hours or 6 years	Add Cat ELC Extender at 6000 service hours or one half of service life
		Cat ELI (water based) ⁽³⁾	12000 hours or 6 years	Add Cat ELC Extender at 6000 service hours or one half of service life
	Min requirements	Cat EC-1 specification and "ASTM D6210" and Organic Additive Technology (OAT) based on a combination of a monocarboxylic acid and a dicarboxylic acid Phosphate, borate, and silicate free Tolyltriazole: minimum typical concentration of 900 ppm Nitrite: minimum typical concentration of 500 ppm in new coolants	6000 hours or 6 years	Add Extender at 3000 service hours or one half of service life

(continued)

(Table 25, contd)

Recommendations for Finished Coolants for use in Cat engines				
Conventional coolants and commercial extended life coolants that do not meet EC-1	Acceptable	Cat DEAC	3000 hours or 3 years	SCA at maintenance intervals
		Cat SCA (water based) ⁽³⁾	3000 hours or 2 years	SCA at maintenance intervals
	Min requirements for fully formulated Heavy Duty Commercial coolants	"ASTM D6210" and Nitrite (as NO ₂) concentration: Minimum of 1200 ppm (70 grains/US gal) and maximum of 2400 ppm (140 grains/US gal) Silicon concentration: minimum of 100 ppm and maximum of 275 ppm	3000 hours or 2 years	SCA at maintenance intervals
	Min requirements for Commercial coolants requiring SCA precharge	"ASTM D4985" and ⁽³⁾ Nitrite (as NO ₂) concentration: Minimum of 1200 ppm (70 grains/US gal) and maximum of 2400 ppm (140 grains/US gal) Silicon concentration: minimum of 100 ppm and maximum of 275 ppm	3000 hours or 1 year	SCA at initial fill and SCA at maintenance intervals
	Min requirements for SCA and water	Commercial supplemental coolant additive and water	3000 hours or 1 year	Per manufacturer recommendations

(1) New Coolants at 50 volume percent diluted. Coolants that are prediluted at the coolant manufacturer must be diluted with water that meets Reagent 4 "ASTM D1193" requirements.

(2) Maintain the in-service coolant at the given limits.

(3) Water-based coolants are not allowed for use in machines that has NO_x reduction aftertreatment devices, in engines that has AATAC and in Marine engines C7-C32

Table 26

Special Requirements	
Cat C7-C32 Marine Engines with heat exchangers	Minimum of 30% glycol is required. 50% Glycol is recommended. Water alone or water with SCA or with ELI is NOT allowed.
Cat diesel engines equipped with air-to-air aftercooling (ATAAC)	
Cat 3618 engine model	Water-ELI is recommended. Water-SCA is acceptable. Glycol-based coolants are NOT allowed.
Cat 3500C engine model Marine EPA Tier 3 capable engines (heat exchanger cooled and keel cooled configurations)	Maximum of 20% glycol is allowed in the aftercooler circuit. ⁽¹⁾ (not applicable to the jacket water circuit, which is capable of 50% glycol)

(1) For freezing protection of -5° C (23° F) temperatures and lower, consult your Cat dealer for guidance.

When referring to the Service Life in table 25, use the interval that occurs first. These coolant change intervals are only achievable with annual S-O-S Services Level 2 coolant sampling analysis.

Refer to the engine Operation and Maintenance Manual for the correct interval for replacement of the cooling system water temperature regulator.

Extended life coolants require the one time maintenance addition of an extender at coolant service mid-life. For commercial coolants, do NOT use an extender with a coolant unless the extender has been approved by the coolant manufacturer for use with the coolant. The coolant manufacturer is responsible to ensure compatibility and acceptable performance. Failure to follow these recommendations can result in shortened cooling system component life.

Conventional coolants require the maintenance addition of SCA throughout the expected life. For commercial coolants, do NOT use an SCA unless approved by the coolant supplier for use with the coolant. The coolant manufacturer is responsible to ensure compatibility and acceptable performance.

"ASTM D4985" and "ASTM D6210" require coolants that are properly dosed with SCA and that are in a properly maintained cooling system in normal service to be suitable for use for a maximum of 1 year ("ASTM D4985") and 2 years ("ASTM D6210"). **The suitability for use requirement is the direct responsibility of the coolant manufacturer and SCA manufacturer.** Consult with the coolant and/or SCA manufacturer concerning the suitability of the products for use in a given application.

Cat DEAC does not require a treatment with an SCA at the initial fill.

A commercial heavy-duty coolant/antifreeze that meets the "ASTM D6210" specification does not require a treatment with an SCA at the initial fill.

A commercial heavy-duty coolant/antifreeze that only meets "ASTM D4985", WILL require a treatment with an SCA at the initial fill and has to fulfill all the requirements listed in the "Technical Requirements for Commercial Extended Life Coolants" table. The user and the coolant manufacturer are responsible to ensure the SCA is compatible. Compatibility is based on the recommendations provided by the coolant manufacturer and SCA manufacturer. For example, an extended life coolant that meets the "ASTM D4985" specification may not be compatible with an SCA designed for use with conventional coolants. The coolant manufacturer is responsible to provide sources of compatible SCAs. The coolant manufacturer and SCA manufacturer are responsible to demonstrate a positive influence on reducing cavitation corrosion in an operating diesel engine.

Read the label or the instructions that are provided by the manufacturer of the commercial heavy-duty coolant/antifreeze.

When adding SCA at initial fill to a coolant/antifreeze that only meets "ASTM D4985", the user and the coolant manufacturer must ensure the SCA is compatible with the antifreeze/coolant. The addition must be based on the recommendations provided by the coolant manufacturer and SCA manufacturer. One of the test methods required to be used to help ensure SCA compatibility with the antifreeze/coolant concentrate is "ASTM D5828-97". Follow the test procedure using the antifreeze/coolant of interest to compare the SCA of interest with the reference SCA. The ratio of insoluble for SCA to reference SCA must be < 1 . Total insoluble should not exceed 4.0 mL for a 6% SCA mixture. The SCA manufacturer is responsible for ensuring the SCA is compatible with water meeting the "Caterpillar Minimum Acceptable Water Quality Requirements" as found in this Special Publication, and is found in "ASTM D6210", Table X1.1.

The coolant manufacturer and the SCA manufacturer are responsible to ensure that the products will not cause cooling system harm.

Cat ELC can be recycled into conventional coolants.

Cat ELC, Cat ELI, Cat DEAC, Cat Extender, and Cat SCA are available in several container sizes. The availability of part numbers will vary by the region. Consult your Cat dealer.

In stationary and marine engine applications that do not require protection from boiling or freezing, except as noted in Table 26, Cat ELI in water or SCA and water are acceptable. **Caterpillar recommends a minimum of 7.5 percent concentration of Cat ELI in those cooling systems using Cat ELI. Caterpillar recommends a minimum of 6 percent to a maximum of 8 percent concentration of Cat SCA in those cooling systems using Cat SCA.** Distilled water or deionized water is preferred in those systems. If distilled or deionized water is not available, use water that meets or exceeds the minimum acceptable water requirements that are listed in this Special Publication, "General Coolant Information" article.

After the addition of water and proper mixing, the concentration of Cat ELI can be determined using the 360-0744 digital Brix refractometer. Refer to the tool operating manual for that refractometer for more information. The concentration of a sample of in-use Cat ELI taken from the cooling system can also be determined using this refractometer

NOTICE

All Cat engines that are equipped with a Cat NOx Reduction System require a minimum of 50 percent glycol to help prevent cavitation damage and boiling of the engine coolant. These engines include Tier 4 engines.

NOTICE

Do not use a commercial coolant/antifreeze that only meets the ASTM "D3306" or equivalent specification. This type of coolant/antifreeze is made for light duty automotive applications.

Use only the coolant/antifreeze that is recommended.

Caterpillar recommends a 50 volume percent glycol and water of proper quality. This mixture will provide optimum heavy-duty performance as a coolant/antifreeze.

Maintain a concentration level of nitrites in the cooling system that is between 1200 ppm (70 grains/US gal) and 2400 ppm (140 grains/US gal). S-O-S coolant analysis is the preferred method to check SCA concentration. Alternatively, nitrite levels can be tested with the following tools:

- 4C-9301 nitrite level test strips, English instructions only, use with glycol-based coolants such as Cat DEAC
- 286-2578 nitrite level test strips, English, French, and Spanish instructions, use with glycol-based coolants such as Cat DEAC
- 298-5311 nitrite level titration kit, subject to regional availability, use only with mixtures of water and SCA. Not for use with glycol-based coolants.

Frequently check the concentration of glycol in glycol-based coolant. Use a coolant/battery tester. Two products are available from Cat dealers. 245-5829 is an analogue refractometer that shows the freeze protection level of the coolant in both degrees Celsius and degrees Fahrenheit. 360-0774 is a digital Brix refractometer.

Maintain the proper concentrations of glycol and additives in the coolant. Lowering the concentration of glycol or additives will lower the ability of the coolant to protect the system from pitting, from cavitation, from erosion, and from deposits.

Do not top off the cooling system with water unless there is a specific need to adjust the water/glycol ratio. Compatible 50/50 (water/glycol) coolant is typically used and recommended when cooling system top off is required.

Clean the cooling system for the following reasons:

- Contamination of the cooling system
- Overheating of the engine
- Foaming of the coolant
- Changing from conventional heavy-duty coolant/antifreeze to Cat ELC or ELC-1 coolant

Note: Air pockets can form in the cooling system if the cooling system is filled at a rate that is greater than 20 L (5 US gal) per minute. The maximum recommended cooling system fill rate for some smaller engine models will be less. Refer to the engine Operation and Maintenance Manual for exceptions.

After you drain the cooling system and after you refill the cooling system, operate the engine. Operate the engine without the filler cap until the coolant level stabilizes. Ensure that the coolant is maintained to the proper level.

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Extended Life Coolant

SMCS Code: 1350; 1352; 1395

Cat ELC

Caterpillar provides Cat ELC (Extended Life Coolant) for use in the following applications:

- Heavy-duty diesel engines
- Automotive applications

When Cat ELC is compared to conventional coolants, the Cat ELC anti-corrosion package is based on a different additive system. Cat ELC has been formulated with the correct amounts of additives. Superior corrosion protection is provided for all metals that are in engine cooling systems.

Cat ELC extends the service life of the coolant to 12000 service hours or 6 years. Cat ELC does not require the frequent addition of the Cat ELC Extender additive. An Extender is the only additional maintenance that is needed at 6000 service hours or one half of the Cat ELC service life.

Cat ELC is available in a 1:1 premixed cooling solution with distilled water. The premixed Cat ELC provides freeze protection to -37 °C (-34 °F). The premixed Cat ELC is recommended for the initial fill of the cooling system. The premixed Cat ELC is also recommended for topping off the cooling system.

Cat ELC Concentrate is also available. Cat ELC Concentrate can be used to lower the freezing point to -52°C (-62°F) for arctic conditions.

Containers of several sizes are available. Refer to this Special Publication, "Coolant Recommendations" article for available quantities and part numbers.

Note: Cat ELC can be used in most diesel and gasoline OEM engines. Cat ELC meets the performance requirements of "ASTM D4985" and "ASTM D6210" for heavy-duty low silicate antifreeze/coolants. Cat ELC also meets the performance requirements of "ASTM D3306" for automotive applications.

Commercial Extended Life Coolant

NOTICE

Cat does not warrant the quality or performance of non-Cat fluids.

In order to be used in Cat diesel engine cooling systems at the published service intervals, select a commercial extended life coolant that meets all the requirements given in Table 27 in this Special Publication.

Table 27

Technical Requirements for Commercial Extended Life Coolants	
Specifications	Cat EC-1 and "ASTM D6210"
Additional Requirements	Organic Additive Technology (OAT) based on a combination of a monocarboxylic acid and a dicarboxylic acid
	Phosphate, borate, and silicate free
	Minimum typical tolyltriazole level of 900 ppm for new coolants
	Minimum typical nitrite level of 500 ppm in new coolants"
Maintenance	One time addition of an extender at the mid-life of the coolant in order to maintain the coolant nitrite level between 300 - 600 ppm

Note: The Cat EC-1 specification describes the minimum requirements for extended life coolants.

Use an extender that is recommended by the EC-1 coolant supplier at mid-life of the coolant.

Commercial coolants that do not meet the minimum requirements defined in this Special Publication are not allowed for use in Cat engines.

Commercial extended life coolant used in Cat engines must meet all requirements given in Table 27. If the ELC does meet the requirements, the service interval listed in this Special Publication may not be used. Follow the maintenance guidelines for the coolant from the supplier of the commercial extended life coolant. Follow the Cat guidelines for the quality of water and the specified coolant change interval.

Note: Coolants must be tested against the Cat EC-1 specification requirements. Coolants that only claim to meet the performance requirements of the Cat EC-1 specification may not meet all the minimum requirements.

In order to be marketed as a product that meets Cat EC-1, all Cat EC-1 specification requirements must be met. Requirements include, but are not limited to the following:

- Physical and Chemical Properties
- Compatibility Characteristics
- Bench Testing
- Field Testing

The field test includes the use of the following requirements:

- Radiator types
- Minimum field test duration
- Minimum number of diesel engines
- Cat diesel engine models of the required minimum power rating

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Extended Life Coolant Cooling System Maintenance

SMCS Code: 1350; 1352; 1395

Proper Additions to the Cat ELC (Extended Life Coolant)

NOTICE

Use only Cat products or commercial products that have passed Cat EC-1 specification for pre-mixed or concentrated coolants.

Use only Cat ELC Extender with Cat ELC.

Do NOT use conventional SCA with Cat ELC. Mixing Cat ELC with conventional coolants and/or conventional SCA reduces the Cat ELC service life.

Do NOT mix brands or types of coolant. Do NOT mix brands or types of SCA and/or brands or types of extenders. Different brands or types may use different additive packages to meet the cooling system requirements. Different brands or types may not be compatible.

Failure to follow the recommendations can reduce cooling system component life unless appropriate corrective action is performed.

Test the glycol concentration in the coolant and test the nitrite concentration in the coolant. Follow the maintenance information provided in this Special Publication, "Coolant and General Maintenance Recommendations" section.

During daily maintenance, use the premixed Cat ELC as a cooling system top-off. This top-off will bring the coolant up to the proper level. Use Cat ELC Concentrate to restore the proper glycol concentration in the coolant system. This addition should be done before the engine is exposed to freezing temperatures. Do not use a conventional coolant to top-off a cooling system that is filled with Cat ELC.

Do not use a conventional coolant to top-off a cooling system that is filled with Cat ELC.

Cat ELC Extender

Cat ELC Extender is added to the cooling system halfway through the Cat ELC or Cat ELI service life. Treat the cooling system with Cat ELC Extender at 6000 hours or one half of the coolant service life. Refer to your machine Operation and Maintenance Manual for exceptions. Refer to the "Part Number of Coolant" table in this Special Publication, "Coolant Recommendations" article for available quantities and part numbers.

Use the formula in Table 28 to determine the proper amount of Cat ELC Extender for your cooling system. Refer to Operation and Maintenance Manual, "Refill Capacities and Recommendations" in order to determine the capacity of the cooling system.

Table 28

Formula For Adding Cat ELC Extender To Cat ELC
$V \times 0.02 = X$
V is the total capacity of the cooling system.
X is the amount of Cat ELC Extender that is required.

Table 29 is an example for using the formula that is in Table 28. This example is based on the capacity of a D8R Track-Type Tractor with a cooling system capacity of 92 L (24.3 US gal).

Table 29

Example Of The Equation For Adding Cat ELC Extender To Cat ELC		
Total Volume of the Cooling System (V)	Multiplication Factor	Amount of Cat ELC Extender that is Required (X)
946 L (250 US gal)	$\times 0.02$	19 L (5 US gal)

NOTICE

When using Cat ELC, do not use conventional SCAs, or, if equipped, SCA maintenance elements. In order to avoid SCA contamination of an ELC system, remove the SCA element base and plug off or bypass the coolant lines.

Cat ELC Cooling System Cleaning

Note: If the cooling system is already using Cat ELC, cleaning agents are not required at the specified coolant change interval. Cleaning agents are only required if the system has been contaminated by the addition of some other type of coolant or by cooling system damage.

Clean water is the only cleaning agent that is required when Cat ELC is drained from a properly maintained cooling system.

After the cooling system is drained and then refilled, operate the engine while the cooling system filler cap is removed. Operate the engine until the coolant level reaches the normal operating temperature and until the coolant level stabilizes. As needed, add the coolant mixture in order to fill the system to the proper level.

Recycling Cat ELC

Cat ELC can be recycled into conventional coolants. The drained coolant mixture can be distilled in order to remove the ethylene glycol and the water. The ethylene glycol and the water can be reused. The distilled material does not contain the additives that are required as either Cat ELC or Cat DEAC. Consult your Cat dealer for more information. Recycled coolants should meet the most current revision level of "ASTM D6210".

Changing to Cat ELC

To change from heavy-duty coolant/antifreeze to the Cat ELC, perform the following steps:

NOTICE

Care must be taken to ensure that fluids are contained during performance of inspection, maintenance, testing, adjusting and repair of the product. Be prepared to collect the fluid with suitable containers before opening any compartment or disassembling any component containing fluids.

Refer to Special Publication, NENG2500, "Caterpillar Dealer Service Tool Catalog" and to Special Publication, PECJ0003, "Cat Shop Supplies and Tools" for tools and supplies suitable to collect and contain fluids on Cat products.

Dispose of all fluids according to applicable regulations and mandates.

1. Drain the coolant into a suitable container.
2. Dispose of the coolant according to local regulations.
3. If equipped, remove the empty SCA maintenance element and remove the element base. Plug the coolant lines or bypass the coolant lines.

NOTICE

Do not leave an empty SCA maintenance element on a system that is filled with Cat ELC.

The element housing may corrode and leak causing an engine failure.

Remove the SCA element base and plug off or by-pass the coolant lines.

4. Flush the system with clean water in order to remove any debris.
5. Use Cat Quick Flush Cooling System Cleaner for cooling systems in order to clean the system. Cat Quick Flush Cooling System Cleaner is available in various sizes. Part numbers are 4C-4609 (0.5 L (0.125 US gal)) through 4C-4613 (208.2 L (55 US gal)). Follow the instructions on the label using a 6-10% concentration of cleaner in water.
6. Drain the cleaner into a suitable container. Flush the cooling system with clean water.

Note: Deposits that remain in the system may be loosened and removed by the Cat ELC.

7. In systems with heavy deposits, disconnecting the hoses may be necessary. Clean the deposits and debris from the hoses and the fittings. Install the hoses and tighten the hose fittings. Refer to Specifications, SENR3130, "Torque Specifications" for the proper torques. Pipe threads may also need to be cleaned and sealed. Seal the threads with 5P-3413 Pipe Sealant.

Note: Replace hoses that are cracked, soft, or that have other signs of damage. Tighten all hose clamps and fittings.

8. Fill the cooling system with clean water and operate the engine until the engine is warmed to 49 °C to 66 °C (120 °F to 151 °F).

NOTICE

Improper or incomplete rinsing of the cooling system can result in damage to copper and other metal components.

To avoid damage to the cooling system, make sure to completely flush the cooling system with clear water. Continue to flush the system until all signs of the cleaning agent are gone.

9. Drain the cooling system into a suitable container and flush the cooling system with clean water.

NOTICE

The cooling system cleaner must be thoroughly flushed from the cooling system. Cooling system cleaner that is left in the system will contaminate the coolant. The cleaner may also corrode the cooling system.

10. Repeat Steps 8 and 9 until the system is clean.
11. Fill the cooling system with the Cat ELC.
12. Operate the engine until the engine is warmed. While the engine is running, inspect the engine for leaks. Tighten hose clamps and connections in order to stop any leaks.
13. Attach the Special Publication, PMEP5027, "Label" to the cooling system filler for the engine in order to indicate the use of Cat ELC.

Note: Clean water is the only flushing agent that is required when Cat ELC is drained from a properly maintained cooling system.

Cat ELC Cooling System Contamination

NOTICE

Mixing Cat ELC with other products reduces the effectiveness of the Cat ELC and shortens the Cat ELC service life. Use only Cat products or commercial products that have passed the Cat EC-1 specification for premixed or concentrate coolants. Use only Cat ELC Extender with Cat ELC. Do NOT mix brands or types of coolants. Failure to follow these recommendations can result in shortened cooling system component life.

Cat ELC cooling systems can withstand contamination to a maximum of 10 percent of conventional heavy-duty coolant/antifreeze and/or SCA. The advantages of Cat ELC are reduced. If the contamination exceeds 10 percent of the total system capacity, perform ONE of the following procedures:

- If the cooling system contamination is caused by cooling system damage, follow the procedures under the "Changing to Cat ELC" heading. Also follow the procedures if the engine has been operated since being contaminated with more than 10 percent conventional heavy-duty coolant/antifreeze and/or SCA. Certain types of cooling system contamination may require disassembly of the cooling system and manual cleaning of system components.
- If the cooling system is contaminated with more than 10 percent conventional heavy-duty coolant/antifreeze and/or SCA, but the engine has not been operated, drain the cooling system into a suitable container. Dispose of the coolant according to local regulations. Thoroughly flush the system with clean water. Fill the system with the Cat ELC.
- Maintain the system as a conventional DEAC (Diesel Engine Antifreeze/Coolant) or other conventional coolant. Submit a coolant sample for Level 2 S-O-S Coolant Analysis to determine the coolant condition. Maintain a 3 to 6 percent SCA concentration in the coolant. Change the coolant at the interval that is recommended for Cat DEAC or at the interval that is recommended for the conventional commercial coolants.

i04286208

Extended Life Inhibitor (ELI)

SMCS Code: 1350; 1352; 1395

Cat Extended Life Inhibitor (ELI) is water-based coolant that does not contain glycol. Cat ELI is for applications that do not require freeze protection. Exceptions are listed in this. Failure to follow these recommendations can or will result in failures.

Cat ELI is a corrosion inhibitor concentrate that is mixed to approximately 7.5 % by volume with water. Cat ELI has the following characteristics:

- Based on the same organic additive technology that is used in Cat Extended Life Coolant (ELC)
- Does not contain glycol. Designed for use in applications that do not require freeze protection.
- Provides superior corrosion and cavitation protection compared to SCA mixed with water.
- Provides an extended drain interval of up to 6 years or 12,000 hours. The drain interval may be longer as determined by using Cat S-O-S coolant analysis.
- Requires little maintenance compared to conventional SCA mixed with water.

Cat ELI can replace SCA/Water coolant in engine applications that do not require freeze protection.

Exceptions for use of water-based ELI or SCA coolants are listed in this Special Publication, "Coolant Recommendations - Special Requirements Table".

Additional information is available from your Cat Dealer. Refer to Information Release Memo, PELJ1212, "Cat ELI – PERFORMANCE LIKE Cat ELC FOR APPLICATIONS NOT REQUIRING FREEZE PROTECTION". Refer to Table 30 for information about Cat ELI.

Table 30

Part Number	Container Size	Volume of Finished Coolant Produced
351-9431	3.8 L (1 US gal)	50.5 L (13.3 US gal)
351-9432	20 L (5.3 US gal)	267 L (70.5 US gal)
351-9433	208 L (55 US gal)	2773 L (733 US gal)
366-2753 ⁽¹⁾	1000 L (264 US gal)	13333 L (3523 US gal)

⁽¹⁾ NACD and LACD only

Mixing Cat ELI

The recommended water for mixing with Cat ELI concentrate is distilled or deionized water. Water must meet requirements of ASTM 1193, "Type IV Reagent Water Specification". If distilled or deionized water is not available, water should meet the "Caterpillar Minimum Acceptable Water Requirements" provided in this Special Publication.

To ensure a proper concentration, the preferred method is to mix Cat ELI concentrate with water. Then, add the mixed coolant to the engine cooling system. Add the proper amounts of water and Cat ELI into a clean container and mix thoroughly by manual stirring or mechanical agitation.

If the preferred method cannot be performed, a Cat ELI mixture can be made by adding Cat ELI concentrate directly into engine cooling system. Add good quality water until the dilution level is approximately 7.5%. Adequate mixing is attained by operating the engine for at least 30 minutes.

Appropriate mixing rates for available ELI container sizes are provided in Table 30.

After the addition of water and proper mixing, the concentration of Cat ELI can be determined using the 360-0744 digital Brix refractometer.

Changing to Cat ELI

For cooling systems previously running Cat ELC or an extended life coolant that meets Cat EC-1 requirements, drain the cooling system and flush with water. Then refill the cooling system with a mixture of 7.5% Cat ELI in water that meets the "Caterpillar Minimum Acceptable Water Requirements".

For cooling systems previously running a conventional heavy-duty coolant or a water/SCA mixture, follow the steps listed in this Special Publication, "Changing to Cat ELC". Then refill the cooling system with a mixture of 7.5% Cat ELI in water that meets the "Caterpillar Minimum Acceptable Water Requirements".

Cat ELI Maintenance

Maintenance of Cat ELI is similar to Cat ELC. A coolant sample should be submitted for S-O-S Level 2 Coolant Analysis after the first 500 hours of operation and then annually thereafter.

Cat ELC Extender should be added at the midpoint of service life (typically 6,000 hours), or as recommended by S-O-S Coolant Analysis results.

Analysis and interpretation of Cat ELI S-O-S results is similar to the analysis and interpretation of Cat ELC. There will be no glycol and glycol oxidation products, which do not apply to Cat ELI.

The concentration of a sample of in-use Cat ELI taken from the cooling system can also be determined using the 360-0744 digital Brix Refractometer.

The concentration of Cat ELI can be determined using a refractometer such as Cat part number 360-0774.

Note: Clean water is the only flushing agent that is required when Cat ELI is drained from a properly maintained cooling system.

Mixing Cat ELI and Cat ELC

Since Cat ELI and Cat ELC are based on the same corrosion inhibitor technology, Cat ELI can be mixed with Cat ELC. Mixing may be desired when only low level of freeze protection is required. Consult your local Cat dealer to ensure proper mixing of the products to provide adequate freeze protection and corrosion protection.

i04331825

Diesel Engine Antifreeze/ Coolant (DEAC)

SMCS Code: 1350; 1352; 1395

Follow the maintenance information provided in this Special Publication, "Coolant and General Maintenance Recommendations" section.

Cat recommends using Cat DEAC (Diesel Engine Antifreeze/Coolant) for cooling systems that require a high performance conventional heavy-duty coolant/antifreeze. Cat DEAC is alkaline single-phase ethylene glycol type antifreeze that contains corrosion inhibitors and antifoam agents.

Cat DEAC is formulated with the correct amount of Cat SCA (Supplemental Coolant Additive). Do not use Cat SCA at the initial fill when Cat DEAC is used at the recommended 50 percent by volume glycol or higher concentration with recommended water.

Containers of several sizes are available. Consult your Cat dealer for the part numbers.

If concentrated Cat DEAC is used, Caterpillar recommends mixing the concentrate with distilled water or with deionized water. If distilled water or deionized water is not available, use water which has the required properties. For the water properties, see this publication, "General Coolant Information".

Note: Mix the concentrated Cat DEAC and water thoroughly prior to filling the cooling system.

SCA is added to cooling systems that use conventional coolants for one of three reasons:

- to precharge a new conventional coolant that is not fully Formulated. Cat DEAC is fully formulated and does not require SCA
- to provide corrosion protection in water/SCA cooling systems
- to recharge an in service conventional coolant on a maintenance basis to maintain proper inhibitor levels

Conventional coolants typically require SCA additions at approximately 250-300 service hours. The use of SCA helps to prevent the following conditions from occurring:

- Corrosion
- Formation of mineral deposits
- Cavitation erosion of the cylinder liners
- Foaming of the coolant

Cat DEAC (Diesel Engine Antifreeze/Coolant) is formulated with the correct level of Cat SCA. When the cooling system is initially filled with Cat DEAC, adding more Cat SCA is not necessary.

Cat DEAC (Diesel Engine Antifreeze/Coolant) is formulated with the correct level of Cat SCA. When the cooling system is initially filled with Cat DEAC, adding more Cat SCA is not necessary. To ensure that the correct amount of Cat SCA is in the cooling system, the test the concentration on a scheduled basis. Refer to the Operation and Maintenance Manual, "Maintenance Interval Schedule", of the engine.

Containers of Cat SCA are available in several sizes. Refer to this Special Publication, "Conventional Coolant/Antifreeze Cooling System Maintenance" article for available quantities and part numbers.

Note: Do not exceed a 6 percent maximum concentration of SCA. Maintain a 3 to 6 percent SCA concentration in the coolant.

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Supplemental Coolant Additive

SMCS Code: 1350; 1352; 1395

Supplemental Coolant Additive (SCA) – SCA is a general term for an inhibitor package that is added to a cooling system. SCA is added for one of three reasons:

- to precharge a new coolant that is not fully formulated
- to provide corrosion protection in water/SCA cooling systems
- to recharge an in service conventional coolant on a maintenance basis to maintain proper inhibitor levels

Conventional coolants typically require SCA additions at approximately 250-300 service hours.

The use of SCA (supplemental coolant additive) helps to prevent the following conditions from occurring:

- Corrosion
- Formation of mineral deposits
- Cavitation erosion of the cylinder liners
- Foaming of the coolant

Cat DEAC (Diesel Engine Antifreeze/Coolant) is formulated with the correct level of Cat SCA. When the cooling system is initially filled with Cat DEAC, adding more Cat SCA is not necessary. To ensure that the correct amount of Cat SCA is in the cooling system, the test the concentration on a scheduled basis. Refer to the Operation and Maintenance Manual, "Maintenance Interval Schedule" (Maintenance Section) of the specific engine.

Containers of Cat SCA are available in several sizes. Refer to this Special Publication, "Conventional Coolant/Antifreeze Cooling System Maintenance" article for available quantities and part numbers.

Note: Do not exceed a 6 percent maximum concentration of SCA. Maintain a 3 to 6 percent SCA concentration in the coolant.

Maintain a concentration level of nitrites in the cooling system that is between 1200 ppm (70grains/US gal) and 2400 ppm (140 grains/US gal). S·O·S coolant analysis is the preferred method to check SCA concentration. Alternatively, nitrite levels can be tested with the following tools:

- 4C-9301 nitrite level test strips, English instructions only, use with glycol-based coolants such as Cat DEAC
- 286-2578 nitrite level test strips, English, French, and Spanish instructions, use with glycol-based coolants such as Cat DEAC
- 298-5311 nitrite level titration kit, subject to regional availability, use only with mixtures of water and SCA. Not for use with glycol-based coolants

i04331875

Conventional Coolant/ Antifreeze Cooling System Maintenance

SMCS Code: 1350; 1352; 1395

NOTICE

Cat does not warrant the quality or performance of non-Cat fluids.

NOTICE

Use Only Approved SCAs. Conventional coolants require the maintenance addition of SCA throughout their expected life. Do NOT use an SCA with a coolant unless specifically approved by the coolant supplier for use with their coolant. It is the responsibility of the coolant manufacturer to ensure compatibility and acceptable performance.

Failure to follow the recommendations can result in shortened cooling system component life.

Cat SCA is compatible with Cat DEAC. If you use non-Cat brand conventional coolants, consult with the coolant manufacturer for information on a compatible SCA.

NOTICE

Do NOT mix brands or types of coolant. Do NOT mix brands or types of SCA and/or brands or types of extenders. Different brands or types may use different additive packages to meet the cooling system requirements. Different brands or types may not be compatible.

Failure to follow the recommendations can reduce cooling system component life unless appropriate corrective action is performed.

If non-Cat conventional coolants that meet Cat minimum published requirements are used, confirm with the coolant manufacturer before using Cat SCA that Cat SCA is acceptable for use with the coolant. Do not exceed the 6 percent maximum concentration. Check the concentration of SCA with a SCA test kit, or check the concentration of SCA with Cat S·O·S coolant analysis.

Cat engine cooling systems should be tested at 250 hour intervals or at the PM Level 1 intervals for the concentration of SCA (Supplemental Coolant Additive).

Note: Acceptable conventional heavy-duty coolant/antifreeze of all types REQUIRE periodic additions of SCA.

Follow the maintenance information provided in this Special Publication, "Coolant and General Maintenance Recommendations" section.

Note: Specific engine applications may require maintenance practices to be periodically evaluated in order to maintain the engine cooling system properly.

The availability of part numbers will vary from one region to another region.

Do not exceed the 6 percent maximum concentration. Check the concentration of SCA with a SCA test kit, or check the concentration of SCA with Cat S·O·S coolant analysis.

Do not use the maintenance spin-on element for the SCA and the liquid for the SCA at the same time. Spin-on elements may not be available for all applications.

Table 31

Cat SCA Requirements for Heavy-Duty Coolant/Antifreeze				
Cooling System Capacity	Initial Fill	250 hours or Intervals for PM Level 1	Spin-on Element at 250 hours or at Intervals for PM Level 1	Quantity of Elements
22 to 30 L (6 to 8 US gal)	0.95 L (32 fl oz)	0.24 L (8 fl oz)	111-2370	1
31 to 38 L (9 to 10 US gal)	1.18 L (40 fl oz)	0.36 L (12 fl oz)	111-2369	1
39 to 49 L (11 to 13 US gal)	1.42 L (48 fl oz)	0.36 L (12 fl oz)	111-2369	1
50 to 64 L (14 to 17 US gal)	1.90 L (64 fl oz)	0.47 L (16 fl oz)	9N-3368	1
65 to 83 L (18 to 22 US gal)	2.37 L (80 fl oz)	0.60 L (20 fl oz)	111-2371	1
84 to 114 L (23 to 30 US gal)	3.32 L (112 fl oz)	0.95 L (32 fl oz)	9N-3718	1
115 to 163 L (31 to 43 US gal)	4.75 L (160 fl oz)	1.18 L (40 fl oz)	111-2371	2
164 to 242 L (44 to 64 US gal)	7.60 L (256 fl oz)	1.90 L (64 fl oz)	9N-3718	2

Cooling systems of larger capacities than provided in Table 31 should follow the equation given in Table 39 for appropriate amount of SCA required at initial fill. The equation given in Table 41 is the appropriate amount of SCA and water at maintenance intervals.

Adding the SCA to Conventional Coolant/Antifreeze at Initial Fill

Table 32

Equation For Adding The Cat SCA To Water At The Initial Fill ⁽¹⁾
$V \times 0.07 = X$ V is the total volume of the cooling system. X is the amount of Cat SCA that is required.

⁽¹⁾ For fluids that only meet the "ASTM D4985" specification

Table 33 is an example for using the equation that is in Table 32.

Table 33

Example Of The Equation For Adding The Cat SCA To Water At The Initial Fill		
Total Volume of the Cooling System (V)	Multiplication Factor	Amount of Cat SCA that is Required (X)
946 L (250 US gal)	$\times 0.07$	66 L (18 US gal)

Adding the SCA to Conventional Coolant/Antifreeze For Maintenance

Conventional heavy-duty coolant/antifreeze of all types REQUIRE periodic additions of a supplemental coolant additive.

Test the coolant/antifreeze periodically for the concentration of SCA. For the interval, see the Operation and Maintenance Manual, "Maintenance Interval Schedule", for your engine. SCA test kits are available from your Cat dealer. Test the concentration of SCA or submit a coolant sample to your Cat dealer. Refer to this Special Publication, "S-O-S Services Coolant Analysis", article.

Additions of SCA are based on the results of the test or based on the results of the coolant analysis. The size of the cooling system determines the amount of SCA that is needed.

Table 34

Equation for the Addition of Cat SCA To Water For Maintenance
$V \times 0.023 = X$ V is the total volume of the cooling system. X is the amount of Cat SCA that is required.

Table 35 is an example for using the equation that is in Table 34.

Table 35

Example of the Equation for the Addition of Cat SCA To Water For Maintenance		
Total Volume of the Cooling System (V)	Multiplication Factor	Amount of Cat SCA that is Required (X)
946 L (250 US gal)	× 0.023	22 L (6 US gal)

Note: Specific engine applications may require maintenance practices to be periodically evaluated in order to maintain the engine cooling system properly.

Cleaning the System of Heavy-Duty Coolant/Antifreeze

Before Cat SCA can be effective, the cooling system must be free from rust, scale, and other deposits. Preventive cleaning helps avoid downtime caused by expensive out-of-service cleaning required for extremely dirty and neglected cooling systems.

Cat Cooling System Cleaners

- Dissolves or depresses mineral scales, corrosion products, light oil contaminations, and sludges
- Cleans the cooling system after used coolant is drained or before the cooling system is filled with new coolant
- Cleans the cooling system whenever the coolant is contaminated or whenever the coolant is foaming
- The "Standard" version of the Cat Cooling System Cleaners clean the cooling system while still in service.
- Reduces downtime and cleaning costs
- Helps avoid costly repairs from pitting and other internal problems caused by improper cooling system maintenance
- Can be used with glycol-based antifreeze
- For the recommended service interval, refer to the Operation and Maintenance Manual, "Maintenance Interval Schedule" for your engine.

Cat Standard Cooling System Cleaners are designed to clean the cooling system of harmful scale and corrosion without removing the engine from service. The cleaners, both "Standard" and "Quick Flush" can be used in all Cat engine cooling systems. Consult your Cat dealer for part numbers.

Note: These cleaners must not be used in systems that have been neglected or that have heavy scale buildup. These systems require a stronger commercial solvent that is available from local distributors.

Prior to performing a cleaning of the cooling system, take a 1-liter (1-quart) sample of coolant from the engine while in operation into a clear container. Take the sample shortly after start-up while the coolant is not yet hot. The coolant should be adequately mixed by the water pump. Allow the sample to sit for 2 hours. If a visible oil layer is present, neither the Standard cleaners nor Quick Flush cleaner will be fully effective. First, drain the coolant and then perform the procedure given below (using non-foaming dish detergent), followed by the procedure for the Quick Flush cleaner.

Procedure for Cleaning an Oil Contaminated Cooling System

1. Drain the cooling system.
 2. Fill the cooling system with acceptable quality water.
- Note:** Refer to the "Caterpillar Minimum Acceptable Water Quality Requirements" in this Special Publication.
3. Start the engine and run the engine until the thermostat opens.
 4. Add 0.473 L (0.5 qt) of 269-1948 non-foaming detergent. If the cooling system capacity exceeds 113.6 L (30 US gal), add enough detergent to equal approximately 2-3% cooling system capacity.

Note: Pre-dissolve the detergent in approximately 19 L (5 US gallons) of acceptable quality water. Add this mixture directly to the cooling system and top off the cooling system with water.

5. Run the engine for at least 30 minutes. Drain the cooling system.
6. Remove a small sample of the detergent solution from the cooling system. Allow the solution to sit for at least 30 minutes and check for signs of a visible oil layer on top. If oil is still present, repeat the procedure.

Note: Corrosion of the metal can occur if the detergent solution is left in the cooling system for longer than 1 hour.

7. Flush the cooling system, if there is no visible oil layer in the solution. Fill the cooling system with acceptable quality water. Run the engine for 20 minutes and then drain the water.
8. Perform the cleaning procedure found in this Special Publication for "Cat Cooling System Cleaner - Quick Flush", if additional removal of scale, rust, and inhibitor deposits from the previous coolant is needed.
9. If additional cleaning is not needed, refill the cooling system with new coolant.

Table 36

Cat Cooling System Cleaner for use with Quick Flush Method	
Cleaner part number	Size of Container
4C-4609	0.5 L (0.125 US gal)
4C-4610	1 L (0.25 US gal)
4C-4611	3.8 L (1 US gal)
4C-4612	19 L (5 US gal)
4C-4613	208 L (55 US gal)

Procedure for using Cat Cooling System Cleaner - Quick Flush

1. Drain the cooling system.
 2. Refill the cooling system to 90-94% capacity with acceptable quality water.
- Note:** Refer to the "Caterpillar Minimum Acceptable Water Quality Requirements" as found in this Special Publication.
3. Top off the cooling system with Cat Cooling System Cleaner - Quick Flush cleaner so that the solution is 6-10% cleaner.
 4. Run the engine for 1.5 hours.
 5. After allowing adequate time for the system to cool, drain the cooling system.

Note: Corrosion of the metals can occur if the Quick Flush cleaning solution is in the cooling system for longer than 2 hours.

6. Flush the cooling system.
 - a. Fill the cooling system with acceptable quality water.
 - b. Run the engine for 20 minutes.
 - c. Drain the water.

7. Refill the cooling system with new coolant.

Table 37

Cat Cooling System Cleaner - Standard		
Part Number	Volume	Availability
6V-4511	1.89 L (0.5 US gal)	North and South America
185-5121	1.89 L (0.5 US gal)	Europe, Africa, Middle East

Procedure for using Cat Cooling System Cleaner - Standard

1. If necessary, drain off coolant from the cooling system for the amount of the cleaner.
2. Add 1 bottle (1.89 L (0.5 US gal)) of Cat Cooling System Cleaner - Standard for each 30 L of cooling system capacity. Add the cleaner directly to the coolant.
3. Run the engine as usual.
4. After 30 days, drain the cooling system.
5. Flush the cooling system.
 - a. Fill the cooling system with acceptable quality water.
 - b. Run the engine for 20 minutes.
 - c. Drain the water.
6. Refill the cooling system with new coolant.

Recycling Cat DEAC

Cat DEAC can be recycled. The drained coolant mixture can be distilled in order to separate the ethylene glycol and water. The ethylene glycol and the water can be reused. The distilled material does not contain the additives that are classified as either Cat ELC or Cat DEAC. Consult your Cat dealer for more information.

When recycled coolants are used, use only coolants that have been recycled from extended life, heavy-duty, or automotive coolants. Use coolants that were originally manufactured from virgin ethylene or propylene glycol.

Recycled coolants should meet the latest revision of "ASTM D6210".

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Commercial Heavy-Duty Coolant/Antifreeze and SCA (Supplemental Coolant Additive)

SMCS Code: 1350; 1352; 1395

NOTICE

Cat does not warrant the quality or performance of non-Cat fluids.

NOTICE

Do NOT mix brands or types of SCA. Do NOT mix SCAs and extenders.

Failure to follow the recommendations can result in shortened cooling system component life.

NOTICE

Use Only Approved SCAs. Conventional coolants require the maintenance addition of SCA throughout their expected life. Do NOT use an SCA with a coolant unless specifically approved by the coolant supplier for use with their coolant. It is the responsibility of the coolant manufacturer to ensure compatibility and acceptable performance.

Failure to follow the recommendations can result in shortened cooling system component life.

Follow the maintenance information provided in the "Coolant and General Maintenance Recommendations" section in this Special Publication.

Select a commercial diesel engine antifreeze coolant that meets all the requirements given in Table 38. The table contains the requirements for coolant to meet the published service intervals.

The provided requirements are applicable to finished coolants and not for the concentrates. When concentrated coolant/antifreeze is mixed, Cat recommends mixing the concentrate with distilled water or with deionized water. If distilled water or deionized water is not available, water which has the required properties may be used. For the water properties, refer to this Special Publication, "General Coolant Information" article.

Coolant/antifreezes for heavy-duty applications that meet "ASTM D6210" do not require treatment with SCA at the initial fill. Use the recommended 1:1 or higher concentration with recommended water. Treatment with SCA is required on a maintenance basis.

The SCA manufacturer is responsible for ensuring the SCA is compatible with water meeting the "Caterpillar Minimum Acceptable Water Quality Requirements" as found in this Special Publication, and "ASTM D6210-08, Table X1.1". The coolant manufacturer and the SCA manufacturer are responsible to ensure that the products will not cause cooling system harm.

Do not mix brands or types of coolants with different brands or types of SCA or extender.

If using non Cat coolants, refer to the coolant manufacturer for information on a compatible SCA.

Treat the compatible commercial coolant with 3 to 6 percent Cat SCA by volume. Maintain a 3 to 6 percent concentration level of SCA in the cooling system. For more information, refer to this Special Publication, "Conventional Coolant/Antifreeze Cooling System Maintenance" article.

Table 38

Technical Requirements for Commercial Diesel Engine Antifreeze Coolants	
Specifications	ASTM D6210-08 or ASTM D4985-05
Additional Requirements	Silicon: 100 ppm minimum to 275 ppm maximum Nitrites: maintained at 1200ppm (70 grains/US gal) minimum to 2400 ppm (140 grains/US gal) maximum Cat SCA at 3 to 6 percent (if Cat SCA is added)
Maintenance	ASTM D4985-05: Add compatible SCA at initial fill ASTM D6210-08 and ASTM D4985-05: Add compatible SCA at maintenance intervals Clean and flush the cooling system at drain intervals

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Water/SCA (Supplemental Coolant Additive)

SMCS Code: 1350; 1352; 1395

Cat SCA can be added to water of the recommended quality to form a Water/SCA finished coolant. SCA/Water finished coolant is glycol free. SCA/Water finished coolant is for engine applications that do not require freeze protection.

Exceptions are listed in this Special Publication, "Coolant Recommendations - Special Requirements". Failure to follow these recommendations can or will result in failures.

NOTICE

Never use water alone without Supplemental Coolant Additives (SCA) or without inhibited coolant. Water alone is corrosive at engine operating temperatures. In addition, water alone does not provide adequate protection against boiling or freezing.

In engine cooling systems that use water alone, Caterpillar recommends the use of Cat SCA. Cat SCA helps to prevent the following conditions from occurring:

- Corrosion
- Formation of mineral deposits
- Cavitation erosion of the cylinder liner
- Foaming of the coolant

If Cat SCA is not used, select a fully formulated commercial SCA. The commercial SCA must provide a minimum of 2400 mg/L or 2400 ppm (140 grains/US gal) of nitrites in the final coolant mixture.

The quality of the water is an important factor in this type of cooling system. Distilled water or deionized water is recommended for use in cooling systems. If distilled water or deionized water is not available, use water that meets or exceeds the minimum requirements that are listed in the table for recommended water properties in this Special Publication, "General Coolant Information" topic.

A cooling system that uses a mixture of SCA and water only needs more SCA. The SCA concentration in a cooling system that uses SCA and water should be 6 to 8 percent by volume.

Note: Do not exceed the 8 percent maximum concentration. Check the concentration of Cat SCA with a 298-5311 Coolant Nitrite Test Kit for SCA or perform an S·O·S coolant analysis. The test kit includes: testing tool, 30 nitrite test ampoules, instruction, and hardcase. 294-7420 contains refill ampoules for the 298-5311 Coolant Nitrite Test Kit.

Note: The 298-5311 Coolant Nitrite Test Kit is NOT calibrated to test the nitrite levels of conventional coolants or extended life coolants.

Maintain the Cat SCA in the same way as you would maintain a cooling system that uses heavy-duty coolant/antifreeze. Adjust the maintenance for the amount of Cat SCA additions.

Adding the Cat SCA to Water at the Initial Fill

Use the equation that is in this Special Publication, "Conventional Coolant/Antifreeze Cooling System Maintenance" to determine the amount of Cat SCA that is required at the initial fill. This equation is for a mixture of only Cat SCA and water.

Adding the Cat SCA to Water for Maintenance

For the recommended service interval, refer to the Operation and Maintenance Manual, "Maintenance Interval Schedule" for your engine.

Submit a coolant sample to your Cat dealer. See this Special Publication, "S-O-S Services Coolant Analysis" topic.

Additions of Cat SCA are based on the results of the coolant analysis. The size of the cooling system determines the amount of Cat SCA that is required.

Use the equation that is in this Special Publication, "Conventional Coolant/Antifreeze Cooling System Maintenance" to determine the amount of Cat SCA that is required for maintenance, if necessary:

Note: Specific engine applications may require maintenance practices to be periodically evaluated in order to maintain properly the engine cooling system.

SCA and part numbers are available from your Cat dealer.

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S-O-S Services Coolant Analysis

SMCS Code: 1350; 1395; 7542

Testing the engine coolant is important to ensure that the engine is protected from internal cavitation and corrosion. The analysis also tests the ability of the coolant to protect the engine from boiling and freezing. S-O-S coolant analysis can be done at your Cat dealer. Cat S-O-S coolant analysis is the best way to monitor the condition of your coolant and your cooling system. S-O-S coolant analysis is a program that is based on periodic samples.

NOTICE

Do not use the same vacuum sampling pump for extracting oil samples that is used for extracting coolant samples.

A small residue of either type sample may remain in the pump and may cause a false positive analysis for the sample being taken.

Always use a separate pump for oil sampling and a separate pump for coolant sampling.

Failure to do so may cause a false analysis which could lead to customer and dealer concerns.

New Systems, Refilled Systems, and Converted Systems

Perform an S-O-S coolant analysis (Level 2) at the following maintenance intervals.

- Every Year
- Initial 500 service hours

Perform this analysis at the interval that occurs first for new systems, for refilled systems, or for converted systems that use Cat coolant products. This 500 hour check will also check for any residual cleaner that may have contaminated the system.

Recommended Sampling Interval for S-O-S Services Coolant Analysis

Table 39

Recommended Interval		
Type of Finished Coolant	Level 1	Level 2
Cat DEAC Cat SCA Conventional Heavy-Duty Coolants	Every 250 hours ⁽¹⁾⁽²⁾	Yearly ⁽¹⁾⁽²⁾⁽³⁾
Cat ELC Cat ELI Commercial EC-1 Coolants	Optional ⁽³⁾	Yearly ⁽³⁾

(1) The recommended sampling interval for all commercial coolants that meet Cat EC-1 (Engine Coolant specification - 1)

(2) The recommended sampling interval for all conventional heavy-duty coolant/antifreeze.

(3) The Level 2 Coolant Analysis should be performed sooner if a problem is suspected or identified.

Note: Check the SCA (Supplemental Coolant Additive) of the conventional coolant at every oil change or at every 250 hours. Perform this check at the interval that occurs first.

S-O-S Services Coolant Analysis (Level 1)

A coolant analysis (Level 1) is a test of the properties of the coolant.

The following properties of the coolant are tested:

- Glycol concentration for freeze protection and boil protection
- Ability to protect from erosion and corrosion
- pH

- Conductivity
- Visual analysis
- Odor analysis

The results are reported, and appropriate recommendations are made.

S·O·S Services Coolant Analysis (Level 2)

A coolant analysis (Level 2) is a comprehensive chemical evaluation of the coolant. This analysis is also a check of the overall condition of the cooling system.

The S·O·S coolant analysis (Level 2) has the following features:

- Full coolant analysis (Level 1)
- Identification of metal corrosion and of contaminants
- Identification of buildup of the impurities that cause corrosion
- Identification of buildup of the impurities that cause scaling
- Determination of the possibility of electrolysis within the cooling system of the engine

The results are reported, and appropriate recommendations are made.

For more information on S·O·S coolant analysis, consult your Cat dealer.

Exhaust Aftertreatment Fluids Specifications

Diesel Exhaust Fluid (DEF) (For Use in SCR-equipped engines)

104891337

SMCS Code: 108K

General Information

Diesel Exhaust Fluid (DEF) is a liquid that is injected into the exhaust system of engines equipped with Selective Catalytic Reduction (SCR) systems. SCR reduces emissions of nitrogen oxides (NOx) in diesel engine exhaust.

Diesel Exhaust Fluid (DEF) is also known under other names including Aqueous Urea Solution (AUS) 32, AdBlue, or generically referred to as urea.

In engines equipped with SCR emissions reduction system, DEF is injected in controlled amounts into the engine exhaust stream. At the elevated exhaust temperature, urea in DEF is converted to ammonia. The ammonia chemically reacts with NOx in diesel exhaust in the presence of the SCR catalyst. The reaction converts NOx into harmless nitrogen (N₂) and water (H₂O).

DEF Recommendations for Non-Marine Engines

For use in Cat Non-Marine engines, DEF must meet all the requirements defined by the "ISO 22241-1" standard.

The caps of DEF tanks are blue, as required by emissions regulations. Fill DEF only in clearly marked DEF tanks that have the blue cap.

Caterpillar recommends the use of DEF available through the Cat parts ordering system for use in Cat engines equipped with SCR systems. Refer to Table 40 for part number information:

Table 40

Cat Part Number	Container Size
350-8733	2.5 gal bottle
350-8734	1000-L tote

In North America, commercial DEF that is API approved and meets all the requirements defined in "ISO 22241-1" may be used in Cat engines that are equipped with SCR systems.

Outside of North America, commercial DEF that meets all requirements defined in "ISO 22241-1" may be used in Cat engines that are equipped with SCR systems.

The supplier should provide documentation to prove the DEF is compliant with the requirements of "ISO 22241-1".

NOTICE

Cat does not warrant the quality or performance of non-Cat fluids.

NOTICE

Do not use agriculture grade urea solutions. Do not use any fluids that do not meet "ISO 22241-1" Requirements in SCR emissions reduction systems. Use of these fluids can result in numerous problems including damage to SCR equipment and a reduction in NOx conversion efficiency.

DEF is a solution of solid urea that is dissolved in demineralized water to produce a final concentration of 32.5% urea. Most SCR systems are designed to operate only on DEF concentration of 32.5 percent. DEF solution of 32.5% urea has the lowest attainable freeze point of -11.5° C (11.3° F). DEF concentrations that are higher or lower than 32.5% have higher freeze points. DEF dosing systems and "ISO 22241-1" specifications are designed for a solution that is approximately 32.5%.

Marine engines and other specific applications may use urea solutions of 32.5 percent or 40 percent concentrations in engines equipped with SCR systems. Refer to the information given specifically for marine engines in this DEF article and to your engine Operation and Maintenance Manual.

Caterpillar offers a refractometer, Cat part number 360-0774, that can be used to measure DEF concentration. Follow the instructions provided with the instrument. Appropriate commercial portable refractometers can be used to determine urea concentration. Follow the instructions from the manufacturer.

Urea Solution Recommendations for Marine Engines

US waters are an International Maritime Organization (IMO) NOx Emissions Control Area (NECA). Low NOx engines are required in these areas. These engines may require the use of Diesel Exhaust Fluid (DEF) and other urea solutions for engines equipped with Selective Catalytic Reduction (SCR) systems. If required, Cat marine engines are designed to operate on DEF of urea concentrations of 32.5 percent (by weight) or 40 percent (by weight). The crystallization temperature of 40 percent urea solution is 0° C (32° F). If urea solution ambient temperatures are routinely below 5° C (41° F) and supplemental heat is not applied to urea storage, then 32.5 percent solution should be used and maintained at a temperature above -10° C (14° F). Urea solutions should be maintained above the specified freezing temperature. Consult the urea supplier and follow the guidelines provided in this article for solution handling and recommendations.

Vessels that are traveling internationally and that have on/off NOx controls must enable these controls prior to entering a NECA. For US flagged vessels, on/off controls are not allowed without an exemption during international travel. The controls must always be on. Foreign destinations should be reviewed for supply of ULSD fuel and DEF prior to departure. Exemptions for ULSD or DEF use by US flagged vessels may be requested from the US Environmental Protection Agency (EPA). The EPA can be contacted at the following address:

complianceinfo@epa.gov

When used in marine engines, DEF of 32.5 percent urea concentration must meet all the guidelines and quality recommendations given in this Chapter.

When used in marine engines, urea solutions of 40 percent concentration must follow all the DEF guidelines and quality recommendations given in this chapter and must meet the characteristics listed in Table 42 for 40 percent concentration. The supplier should provide documentation to prove that the urea solution is compliant with the characteristics published in Table 42.

Refer to your engine Operation and Maintenance Manual to determine the concentration of urea solution allowed in your engine.

NOTICE

Cat does not warrant the quality or performance of non-Cat fluids and greases.

DEF Guidelines

DEF solution is typically colorless and clear. Changes to color or clarity are indicators of quality issues. Quality of DEF can degrade when stored and handled inappropriately or if DEF is not protected from contamination. Details are provided below.

If quality issues are suspected, testing of DEF should focus on urea percentage, alkalinity as NH₃, and biuret content. DEF that does not pass all these tests or that is no longer clear should not be used.

Note: Caterpillar strongly recommends that customers purchase the pre-mixed DEF urea solution from a reputable supplier. The DEF must satisfy all the specifications of quality given in this chapter of this Special Publication. Urea solutions that are not made of urea and water of the appropriate quality and cleanliness may damage the SCR system. Poor or questionable quality DEF can lead to additional repair and maintenance costs to the customer. Cat warranties do not cover failures caused by or related to use of out of specification urea solutions in Tier 4 Stage IIIB MLIT Step 4 products equipped with SCR systems.

Materials compatibility

DEF is corrosive. Due to the corrosion caused, DEF must be stored in tanks constructed of approved materials. Recommended storage materials:

Stainless Steels:

- 304 (S30400)
- 304L (S30403)
- 316 (S31600)
- 316L (S31603)

Alloys and metals:

- Chromium Nickel (CrNi)
- Chromium Nickel Molybdenum (CrNiMo)
- Titanium

Non-metallic materials:

- Polyethylene
- Polypropylene
- Polyisobutylene
- Teflon (PFA)

- Polyfluoroethylene (PFE)
- Polyvinylidene fluoride (PVDF)
- Polytetrafluoroethylene (PTFE)

Materials NOT compatible with DEF solutions include aluminum, copper, copper alloys, magnesium, zinc, nickel coatings, silver, and carbon steel and solders containing any of the above. Unexpected reactions may occur if DEF solutions come in contact with any non-compatible material or unknown materials.

Bulk storage

Follow all local regulations covering bulk storage tanks. Follow proper tank construction guidelines. Tank volume typically should be 110% of planned capacity. Appropriately vent indoor tanks. Plan for control of overflow of the tank. Heat tanks that dispense DEF in cold climates.

Bulk tank breathers should be fitted with filtration to keep airborne debris from entering the tank. Desiccant breathers should not be used because water will be absorbed, which potentially can alter DEF concentration.

Handling

Follow all local regulations covering transport and handling. DEF transport temperature is recommended to be -5°C (23°F) to 25°C (77°F). All transfer equipment and intermediate containers should be used exclusively for DEF. Containers should not be reused for any other fluids. Ensure that transfer equipment is made from DEF-compatible materials. Recommended material for hoses and other non-metallic transfer equipment include:

- Nitrile Rubber (NBR)
- Fluoroelastomer (FKM)
- Ethylene Propylene Diene Ionomer (EPDM)

The condition of hoses and other nonmetallic items that are used with DEF should be monitored for signs of degradation. DEF leaks are easily recognizable by white urea crystals that accumulate at the site of the leak. Solid urea can be corrosive to galvanized or unalloyed steel, aluminum, copper, and brass. Leaks should be repaired immediately to avoid damage to surrounding hardware.

Cleanliness

Contaminants can degrade the quality and life of DEF. Filtering DEF is recommended when dispensed into the DEF tank. Filters should be compatible with DEF and should be used exclusively with DEF. Check with the filter supplier to confirm compatibility with DEF before using. Mesh-type filters using compatible metals, such as stainless steel, are recommended. Paper (cellulose) media and some synthetic filter media are not recommended because of degradation during use.

Care should be taken when dispensing DEF. Spills should be cleaned immediately. Machine or engine surfaces should be wiped clean and rinsed with water. Caution should be used when dispensing DEF near an engine that has recently been running.

Note: Spilling DEF onto hot components may cause the release of ammonia vapors. Do not breathe ammonia vapors. Do not clean up any spills with bleach.

Stability

DEF fluid is stable when stored and handled properly. The quality of DEF rapidly degrades when stored at high temperatures. The ideal storage temperature for DEF is between -9°C (15.8°F) and 25°C (77°F). DEF that is stored above 35°C (95°F) for longer than 1 month must be tested before use. Testing should evaluate Urea Percentage, Alkalinity as NH_3 , and Biuret content.

The length of storage of DEF is listed in the following table:

Table 41

Storage Temperature	Expected DEF Life
Below 25°C (77°F)	18 months
25°C (77°F) to 30°C (86°F)	12 months
30°C (86°F) to 35°C (95°F)	6 months
Above 35°C (95°F)	test quality before use

Refer to "ISO 22241" document series for more information about DEF quality control.

Note: Dispose of all fluids according to applicable regulations and mandates.

General Characteristics of DEF

For detailed information on the requirements and characteristics of DEF, refer "ISO 22241". For a quick reference, typical characteristics of DEF are given in Table 42.

Table 42

Characteristics for Urea Solutions			
Property	Unit	DEF 32.5 percent	Urea Solution 40 percent
Urea content		32.5 percent ⁽¹⁾	40 percent ⁽²⁾
Alkalinity as NH ₃	Percent	0.2	0.2
Density at 20° C (68° F)	g/L	1.087 - 1.093 ⁽³⁾	1.108 - 1.114 ⁽⁴⁾
Refractive Index at 25° C (77° F)		1.381 - 1.384 ⁽⁵⁾	1.394-1.397 ⁽⁶⁾
Biuret	Percent	0.3 max	
Aldehydes	mg/kg	5 max	
Insoluble Matter	mg/kg	20 max	
Aluminum	mg/kg	0.5 max	
Calcium	mg/kg	0.5 max	
Chromium	mg/kg	0.2 max	
Copper	mg/kg	0.2 max	
Iron	mg/kg	0.5 max	
Magnesium	mg/kg	0.5 max	
Nickel	mg/kg	0.2 max	
Phosphate (PO ₄)	mg/kg	0.5 max	
Potassium	mg/kg	0.5 max	
Sodium	mg/kg	0.5 max	
Zinc	mg/kg	0.2 max	

(1) Acceptable range is 31.8 - 33.2 percent

(2) Acceptable range is 39-41 percent

(3) Target value is 1.090 g/L

(4) Target value is 1.112

(5) Target value is 1.382

(6) Target value is 1.3956

Contamination Control

i04662450

Contamination Control

SMCS Code: 1280; 1348; 3080; 5095; 7581

Defining Contamination

Contamination is defined as the presence of unwanted foreign substances in fluid systems or fluid wetted parts. Contamination alters the properties of fluids, causes damage of fluid systems, and prevents systems and components from attaining the desired reliability and durability. Contamination is the primary cause of fluid system failures.

Contaminants include a wide variety of unwanted substances including but not limited to the following:

- Foreign and abrasive substances such as wear particles, fibers, dirt, and dust
- Chemical substances such as products of combustion that are suspended in the fluids
- Cross contamination of water, coolant, oil, and fuel
- Biological micro-organisms such as algae or fungi
- Physical/chemical contaminants such as products of oxidation and heat

Some contaminants are generated within the fluid system due to the normal operation of the system. Other contaminants are drawn into the system from the outside environment or introduced into the system from contaminated fill fluids or improper maintenance and repair practices.

Particle contaminants are visible to the naked eye if the particles are approximately 40 μm (microns) and larger while smaller particles are not visible. Particle contaminants can cause damage even if the particles are not visible to the naked eye. The critical particle size for wear particles in a modern diesel engine fuel system is 4 μm .

Contaminants of all types can be controlled by following contamination control practices and using appropriate filtration. Refer to your Operation and Maintenance Manual and to your local Cat dealer for recommendations.

Controlling contamination is especially important for current machine systems. Current machine systems such as hydraulic systems and fuel injection systems are designed with even closer tolerances and typically operate at higher pressures for enhanced performance. These design improvements emphasize the importance of higher performing fluids, enhanced fluid filtration, and greatly improved fluid cleanliness levels.

Measuring Cleanliness

Fluid cleanliness can be measured by taking fluid samples from various machine compartments. Your Cat dealer can analyze the samples. Particle contaminants are typically measured by particle counters. Chemical contaminants can be measured by specific analysis techniques such as oxidation, water, or soot tests. Some chemical contaminants, such as water in fuel, can interfere with the particle counters and can be counted as particles. Refer to your Cat S·O·S lab or to your Cat dealer for more information.

The number of particles in fluids is expressed in "ISO (International Organization for Standardization)" ratings. "ISO 4406" Standard (Hydraulic Fluids Method for coding the level of contamination by solid particles) classifies fluid cleanliness by the number and size of particles in 1 milliliter of fluid. "ISO 4406" Standard measures particle size in μm (microns) and reports the resulting count in three code ranges X, Y & Z. The three code range defines the size and distribution of particles in 1 milliliter of fluid:

- The first code range, X represents the number of particles equal to or larger than 4 μm per milliliter of fluid.
- The second code range, Y represents the number of particles equal to or larger than 6 μm per milliliter of fluid.
- The third code range, Z represents the number of particles equal to or larger than 14 μm per milliliter of fluid.

An example of an "ISO 4406" particle count is 18/16/13. Cat "ISO" cleanliness recommendations are expressed as two or three codes, depending on the machine system. The three code range follows "ISO 4406" definitions and is used for liquid fuels such as diesel and gasoline. The two code system, example "ISO -/16/13", is used for certain lubricant systems. In the two code system, the first code range X (number of particles equal to or larger than 4 μm per milliliter of fluid) is not required and is represented by a dash (-). The second code range Y and the third code range Z follow "ISO 4406" definitions. Cat reports the Y and Z codes for lubricating oils to keep consistency with older data and reports.

An example of the particle size and distribution of code numbers "ISO 4406" is given in Table 43

Table 43

ISO 4406 Code	Number of particles in 1 milliliter of fluid		
	4µm and up	6µm and up	14µm and up
"ISO 18/16/13"	1300 - 2500	320 - 640	40 - 80
"ISO 21/19/17"	10000 - 20000	2500 - 5000	80 - 160

Note: Several factors affect the results of particle counts. The factors include the cleanliness of the equipment used to obtain the sample, sample techniques, the cleanliness, and type of sample container, particle counter accuracy (calibration, maintenance, and process), and the environment where the sample is procured. Samples should be taken at representative locations in the fluid circulation system or the fluid distribution system when possible. The sample should be protected adequately from contamination during transport to the lab for analysis. In addition, particle counters may count water droplets and air bubbles as particulate contamination.

Note: American Society for Testing and Measurement has developed "ASTM D7619" "Standard Test Method for Sizing and Counting Particles in Light and Middle Distillate Fuels, by Automatic Particle Counter". This test procedure was developed in 2010 to count and measure the size of dispersed dirt particles, water droplets, and other particles in 1-D and 2-D diesel fuels when the specified particle counter is used. "ASTM D7619" is also applicable to biodiesel fuels.

Cleanliness Standards for Machine Systems

Cat recommends that machine systems be maintained at the factory defined fluid cleanliness targets.

Cat has established minimum fluid cleanliness targets for fuels and fill oils and for machine roll-off (refer to Table 44). Fluids filled into the machine or engine fill tanks are recommended to be at the target levels provided in Table 44 or cleaner. Cleanliness targets for applicable machine component systems is referred to as "Roll-off". Roll-off is defined as the cleanliness specification of the fluid that is to be obtained before the machine returns to work after maintenance and or system invasion repair. When system fill fluids and Roll-off are maintained at or cleaner than the "ISO" cleanliness targets, contamination related effects will be significantly reduced.

Table 44

Caterpillar Minimum Recommended Fluid Cleanliness Targets		
Caterpillar Minimum Recommended Cleanliness Targets for Fluids Dispensed into Machine or Engine Fill tanks ⁽¹⁾	Fill oils	"ISO -/16/13"
	Dispensed fuels	"ISO -/16/13"
Caterpillar Minimum Recommended Machine Roll-off Cleanliness Targets	Hydraulic systems (Implement & Steering)	"ISO -/18/15"
	Electronic Transmissions	"ISO -/18/15"
	Mechanical Transmissions	"ISO -/21/17"
	Differentials, Wheels and Axles ⁽²⁾	"ISO -/18/15"

(1) For engine oils, when filtering the oil prior to dispensing into the engine tank, use engine oil filters of 12 micron absolute efficiency and ensure that the oil temperature is 20° C (68° F) or higher. Refer to the details given in this article.

(2) This cleanliness standard applies only to the Series 700 family of rigid frame trucks, 777 size and larger.

The "fill" fluids cleanliness target is not a fluid "delivery" target. The level of cleanliness for delivered fluids is not specified by Caterpillar. Customers can work with their distributors or carriers to determine the cleanliness level of delivered fluids. However, a more effective and economic means to achieve fill cleanliness targets is to filter the fluids prior to filling into machine tanks as compared with specifying delivery fluid cleanliness level. Follow the guidelines provided in this Contamination Control article.

Although older technology machines may not be able to maintain consistently the recommended cleanliness targets of advanced models, the same contamination control intervention measures such as filtration and subsequent service procedures should be used on all Cat products.

Note: When particle counting new multi-viscosity engine oils, there may be difficulties achieving cleanliness targets because optical particle counters cannot distinguish between particulate contaminants and additives. Do not use optical particle count for the evaluation of used engine oils because soot levels render oil too dark for optical particle counters. Soot levels in used engine oils should be evaluated by using S-O-S Services Oil Analysis.

When filtering engine oil before dispensing into the engine tank or when engine oil kidney looping filtration is done, follow these recommendations:

- Use of engine oil filters of 12 microns absolute efficiency is recommended. Cat Ultra High Efficiency Lube filter is recommended. Consult your Cat dealer for the most current part number.
- Ensure that the temperature of engine oil is 20° C (68° F) or higher.

Note: Filtration of cold multi grade oil is not recommended due to oil thickening and potential additive interference.

Consult your Cat dealer for information and solutions to your oil and fuel analysis needs including particle counting for new and used oils and for fuels.

General Contamination Control Recommendations or Practices

Maintaining a low contamination level can reduce down time and can control the maintenance cost of the machine. The productive life as well as the reliability of components and fluid systems is often increased as a result of proper contamination control practices.

The following are general guidelines for controlling contaminants.

- Refer to the Recommendations for Fuel Systems in this chapter for recommended fuel cleanliness levels and guidelines.
- Refer to the machine Operation and Maintenance Manual for the required maintenance for all machine compartments.
- When you add oil to a machine, use adequate filtration in order to clean the oil to meet the targets provided in Table 44.
- Perform scheduled S-O-S Services Oil Analysis for contamination in order to maintain the recommended ISO cleanliness level of fill and machine fluids. Refer to the S-O-S Oil Analysis section in this Special Publication. The particle count analysis can be performed by your Cat dealer. Particle count can be conducted during the scheduled S-O-S Services Oil Analysis for the compartment. Extra oil samples are not required for the particle count sampling.

- Use only coolants that are recommended by Cat for your machine. Follow the recommended maintenance procedure for the cooling system in the Operation and Maintenance Manual for your machine.
- Maintain the engine air filters and air intake system to avoid unwanted contaminant ingress.
- Follow contamination control practices for the shop area, component, and machine disassembly areas, parts, shop tools, test setups, test areas, storage areas, and waste collection areas, and so on. Keep components clean during inspection, assembly, testing, and filling machines with clean fluids. These practices will enhance component life and reduce downtime associated with contaminants. Your Cat dealer can provide details on proper contamination processes and practices.
- Follow contamination control practices for the workplace and for the worksite. Maintaining clean oil fill fluids saves time and effort and ensures that fill fluids are at the proper cleanliness levels.
- Use properly designed and maintained bulk storage fluids tanks.
- Protect the fluids storage tanks from dirt and water entry by using 4 μm or less absolute efficiency breathers with the ability to remove water.
- Keep the areas around the tanks filler necks clean of debris and water.
- Drain the storage tanks from water and sediments on an annual basis or per fluid supplier recommendations.
- Install and maintain a properly designed and grounded filtration system. Filtration should include at the entry and at the dispensing point. Continuous bulk filtration may be required to ensure that dispensed oils meet the cleanliness target.
- Install desiccant type breathers of 4 μm or less absolute efficiency on the bulk storage tanks.
- Cover, protect, and ensure cleanliness of all connection hoses, fittings, and dispensing nozzles.

Note: Bulk fuel filtration units are available through your Cat dealer. Proper maintenance practices of the bulk filtration systems are available through your Cat dealer.

Contamination Control Recommendations for Fuels

Fuels of "ISO 18/16/13" cleanliness level or cleaner as dispensed into the engine or machine fuel tank should be used in order to reduce power loss, failures, and related down time of engines. This cleanliness level is important for new fuel system designs such as Common Rail injection systems and unit injection systems. These new injection system designs utilize higher fuel pressures and are designed with tight clearances between moving parts in order to meet required stringent emissions regulations. Peak injection pressures in current fuel injection systems may exceed 30,000 psi. Clearances in these systems are less than 5 μm . As a result, particle contaminants as small as 4 μm can cause scoring and scratching of internal pump and injector surfaces and of injector nozzles.

Water in the fuel causes cavitation, corrosion of fuel system parts, and provides an environment where microbial growth in the fuel can flourish. Other sources of fuel contamination are soaps, gels, or other compounds that may result from undesirable chemical interactions in the fuels, particularly in Ultra Low Sulfur Diesel (ULSD). Gels and other compounds can also form in biodiesel fuel at low temperatures or if biodiesel is stored for extended periods. The best indication of microbial contamination, fuel additives, or cold temperature gel is rapid filter plugging of bulk fuel filters or machine fuel filters.

In order to reduce downtime due to contamination, follow these fuel maintenance guidelines in addition to the General Contamination Control Recommendations or Practices given above in this Chapter:

- Use high-quality fuels per recommended and required specifications (refer to the Fuel Chapter in this Special Publication)
- Fill machine fuel tanks with fuels of "ISO 18/16/13" cleanliness level or cleaner, in particular for engines with common rail and unit injection systems. When you refuel the machine, filter the fuel through a 4 μm absolute filter (Beta 4 = 75 up to 200) in order to reach the recommended cleanliness level. This filtration should be located at the device that dispenses the fuel to the engine or machine fuel tank. In addition, filtration at the dispensing point should remove water to ensure that fuel is dispensed at 500 ppm water or less.

- Caterpillar recommends the use of bulk fuel filter / coalescer units which remove both particulate contamination and water in a single pass. These units clean fuel to "ISO 15/13/11" or cleaner and remove free water to 500 ppm (mg/kg) or less. Cat offers heavy-duty filter / coalescer units to accommodate fueling rates from 50 to 300 gpm (gallons per minute). Cat custom designs filter / coalescer units specifically for the conditions of fuel at the worksite if needed.
- Ensure that you use Cat Advanced Efficiency Fuel Filters. Change your fuel filters per recommended service requirements or as needed.
- Drain your water separators daily per the Operation and Maintenance Manual of your machine.
- Drain your fuel tanks of sediment every 500 hours or 3 months per the Operation and Maintenance Manual of your machine.
- Install and maintain a properly designed bulk filter / coalescer filtration system. Continuous bulk filtration systems may be required to ensure that dispensed fuel meets the cleanliness target. Consult your Cat dealer for availability of bulk filtration products.
- Centrifugal filters may need to be used as a pre-filter with fuel that is severely contaminated with gross amounts of water or large particulate contaminants. Centrifugal filters can effectively remove large contaminants, but may not be able to remove the small abrasive particles required to achieve the recommended "ISO" cleanliness level. Bulk filter / coalescers are necessary as a final filter in order to achieve the recommended cleanliness level.
- Install desiccant type breathers of 4 μ m or less absolute efficiency with the ability to remove water on bulk storage tanks.
- Follow proper practices of fuel transport and filtration from storage tank to the machine in order to allow the delivery of clean fuel to machine tank. Fuel filtration can be installed at each transport stage in order to keep the fuel clean.
- Cover, protect, and ensure cleanliness of all connection hoses, fittings, and dispensing nozzles.

NOTICE

In order to meet expected fuel system component life, 4 micron(c) absolute or less secondary fuel filtration is required for all Cat diesel engines that are equipped with common-rail fuel systems. Also, 4 micron(c) absolute or less secondary fuel filtration is required for all Cat diesel engines that are equipped with unit injected fuel systems. For all other Cat diesel engines (mostly older engines with pump, line and nozzle type fuel systems), the use of 4 micron(c) absolute or less secondary fuel filtration is strongly recommended. Note that all current Cat diesel engines are factory equipped with Cat Advanced Efficiency 4 micron(c) absolute fuel filters.

Consult your local Cat dealer for additional information on Caterpillar designed and produced filtration products.



Reference Information Section

Reference Materials

i04058560

Reference Material

SMCS Code: 1000; 7000

The following literature can be obtained through any Cat dealer.

Note: The information that is contained in the listed publications is subject to changes without notice.

Note: Refer to this Special Publication, the respective product datasheet and other special publications, and the appropriate Operation and Maintenance Manual for product application recommendations.

NOTICE

In order to avoid potential damage to your Cat machine and/or Cat engine, only purchase Cat fluids and Cat filters through your Cat dealer or Cat authorized outlets. For a list of authorized Cat parts outlets in your area, consult your Cat dealer.

If you purchase what appear to be Cat fluids and/or Cat filters through other outlets/sources, you are at a very high risk of purchasing counterfeit ("look-alike") products.

Counterfeit or "look-alike" products may visually appear the same as the original Cat product, but the product performance and internal quality will typically be very low.

Counterfeit or "look-alike" products have a very high likelihood of causing and/or allowing engine and/or machine compartment damage.

Coolants

- Special Publication, PMEP5027, "Label - Cat ELC Radiator Label"
- Datasheet, PEHJ0067, "Cat ELC (Extended Life Coolant)" (Worldwide)
- Datasheet, PEHP9554, "Cat DEAC (Diesel Engine Antifreeze/Coolant) (Concentrate)"

Diesel Engine Oil

- Datasheet, PEHJ0159, "Cat DEO-ULS (SAE 15W-40)" (North America - Canada, Mexico, and United States)
- Datasheet, PEHJ0059, "Cat DEO (SAE 10W-30 and SAE 15W-40)" (North America - Canada, Mexico, and United States)
- Datasheet, PEHJ0021, "Cat DEO (SAE 10W-30 and SAE 15W-40)" (Worldwide - except North America, Egypt, Saudi Arabia, and Brazil)
- Datasheet, PEHJ0072, "Cat DEO (SAE 10W-30 and SAE 15W-40)" (Brazil)
- Datasheet, PEHJ0091, "Cat DEO (SAE 10W-30 and SAE 15W-40)" (Egypt and Saudi Arabia)
- Datasheet, PEHP7062, "Cat DEO SYN (SAE 5W-40)"
- Datasheet, PEHJ0093, "Cat DEO (SAE 30 and SAE 40)" (For use in 3600 Series diesel engines, C280 Series diesel engines and in older precombustion chamber diesel engines. Do NOT use in 3500 Series, C175 Series and smaller direct injected diesel engines.)
- Datasheet, PEHP9516, "Cat SAE0 (SAE30 and SAE40)" (For use in certain Cat 3116 and 3126 Marine Diesel Engines with mechanical fuel injection. Refer to this Special Publication, "Engine Oil (3116 and 3126 Marine Engines)" article. Do NOT use in other engine applications.)
- Datasheet, PEHJ0008, "Cat Arctic DEO (SAE 0W-30)" (Canada and United States)

Grease

- Special Publication, PEGJ0035, "Grease Selection Guide"
- Datasheet, PEHP0002, "Cat Advanced 3Moly Grease" (NLGI grade 2)
- Datasheet, NEHP6010, "Cat Ultra 5Moly Grease" (NLGI grades 1 and 2)
- Datasheet, NEHP6011, "Cat Arctic Platinum Grease" (NLGI grade 0)
- Datasheet, NEHP6012, "Cat Desert Gold Grease" (NLGI grade 2)
- Datasheet, NEHP6015, "Cat High Speed Ball Bearing Grease" (NLGI grade 2)

- Datasheet, PEHJ0088, "Cat Multipurpose Grease" (NLGI grade 2)

S·O·S Services

- Special Publication, PEHJ0191, "S·O·S Coolant Analysis"
- Special Publication, PEGJ0047, "How To Take A Good Oil Sample"
- Special Publications, PEDP7036, "S·O·S Fluids Analysis Cornerstone"
- Special Publications, PEHP7076, "Understanding S·O·S Services Tests"
- Special Publication, PEHP7052, "Making the Most of S·O·S Services"
- Special Publication, PEGJ0045, "Reporting Particle Count by ISO Code"
- Special Publication, PEGJ0046, "Understanding Your S·O·S Services Results"

Filters

- Datasheet, PEHP6028, "Cat Ultra High Efficiency Air Filters"
- Datasheet, PEHP7032, "Radial Seal Air Filters"
- Datasheet, PEHP7077, "Cat Turbine Pre-Cleaners"
- Datasheet, PEHP9013, "Air Filter Service Indicator"
- Datasheet, PEHJ0082, "Cat Fuel/Water Separators and Prime Time Priming Pumps"
- Datasheet, PEHP7046, "Fuel Contamination Control"
- Datasheet, PEHJ0068, "Cat Advanced Efficiency Engine Oil Filter"
- Datasheet, PEHJ0165, "Open Crankcase Ventilation Filter"

Miscellaneous

- Special Publication, PECP9067, "One Safe Source"
- Special Publication, AECQ1042, "Caterpillar Product Line Brochure"
- Special Publication, PEWJ0074, "Cat Filter and Fluid Application Guide"

- Datasheet, PEHJ0030, "Cat Synthetic GO (SAE 75W-140)"
- Datasheet, PEHP7058, "Cat GO (SAE 80W-90 and SAE 85W-140)"
- Special Publication, NENG2500, "Caterpillar Dealer Service Tool Catalog"
- Special Publication, GECJ0003, "Cat Shop Supplies and Tools" catalog
- Special Publication, SENR3130, "Torque Specifications"
- Special Publication, SENR9620, "Improving Fuel System Durability" (Package of 10)
- Special Publication, SEBF1018, "Improving Component Durability - Engines" (Package of 10)
- Special Publication, SEBF1020, "Improving Component Durability - Managing Fluid Cleanliness" (Package of 10)
- Special Publication, SEBD0349, "Caterpillar Performance Handbook"
- "ASTM D6469 Standard Guide for Microbial Contamination in Fuels and Fuel Systems"

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Product and Dealer Information

Note: For product identification plate locations, see the section "Product Identification Information" in the Operation and Maintenance Manual.

Delivery Date: _____

Product Information

Model: _____

Product Identification Number: _____

Engine Serial Number: _____

Transmission Serial Number: _____

Generator Serial Number: _____

Attachment Serial Numbers: _____

Attachment Information: _____

Customer Equipment Number: _____

Dealer Equipment Number: _____

Dealer Information

Name: _____ Branch: _____

Address: _____

Dealer Contact

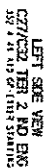
Phone Number

Hours

Sales: _____

Parts: _____

Service: _____



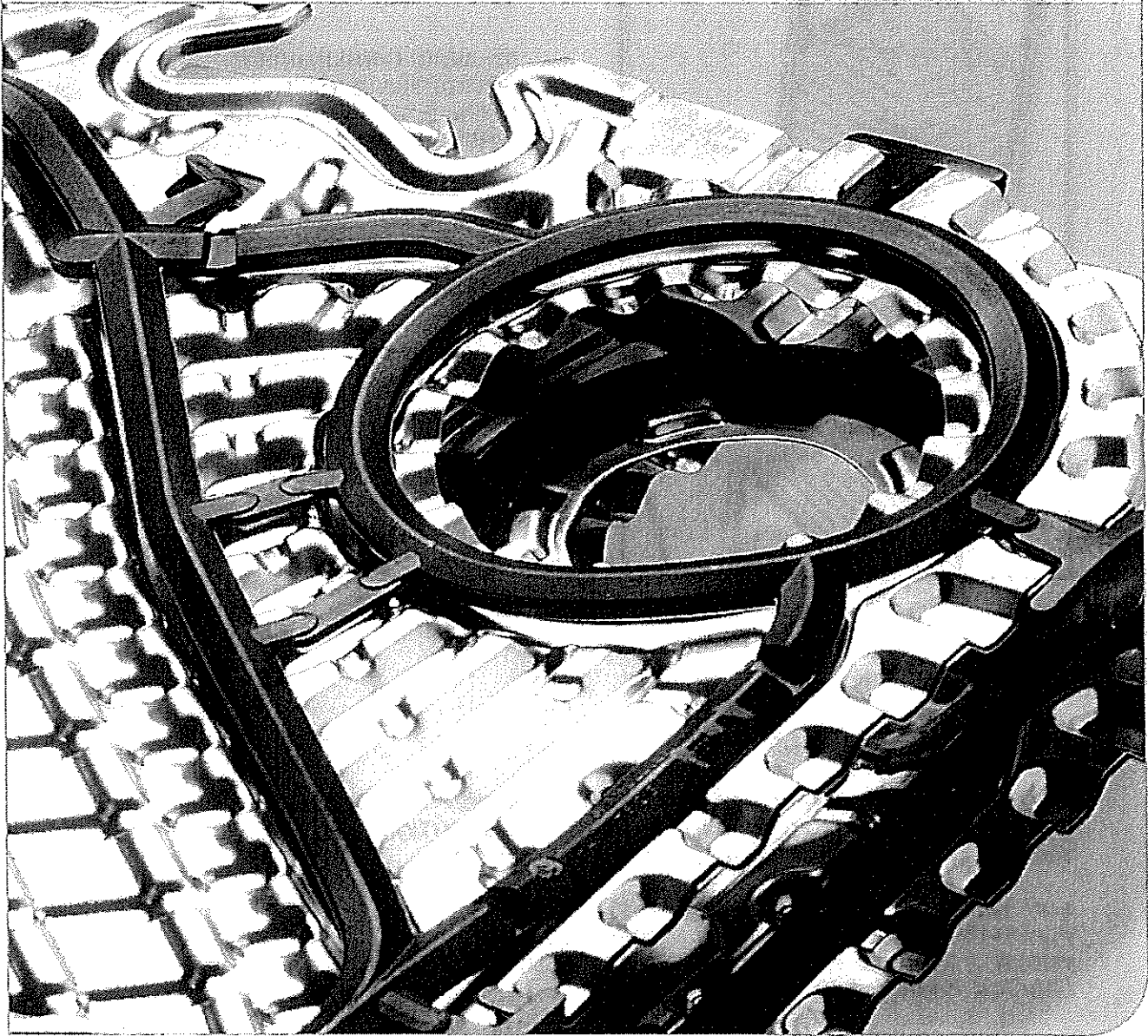
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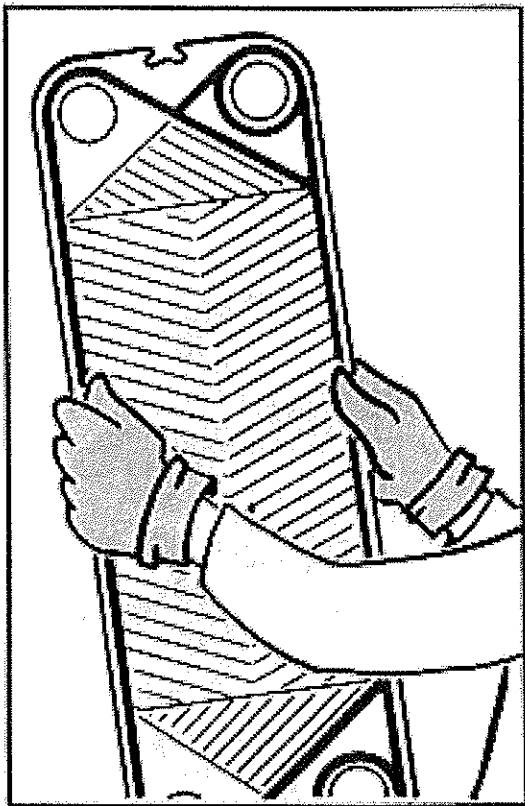
Plate Heat Exchanger

Operational and Maintenance Manual





NOTICE



TO AVOID HAND INJURIES,
PROTECTIVE GLOVES
SHOULD ALWAYS BE WORN
WHEN HANDLING PLATES.

PROTECTIVE SHROUDS

IT IS THE RESPONSIBILITY OF EACH PERSON OPERATING OR REPAIRING EQUIPMENT TO TAKE THE NECESSARY PRECAUTIONS TO COMPLY WITH ALL APPLICABLE SAFETY REGULATIONS.

ALFA LAVAL PROVIDES PROTECTIVE SHROUDS FOR ALL OUR PLATE HEAT EXCHANGERS. THESE SHROUDS WILL PREVENT POSSIBLE INJURIES AND/OR DAMAGE AS A RESULT OF SUDDEN LEAKAGE FROM THE PLATE PACKAGE.

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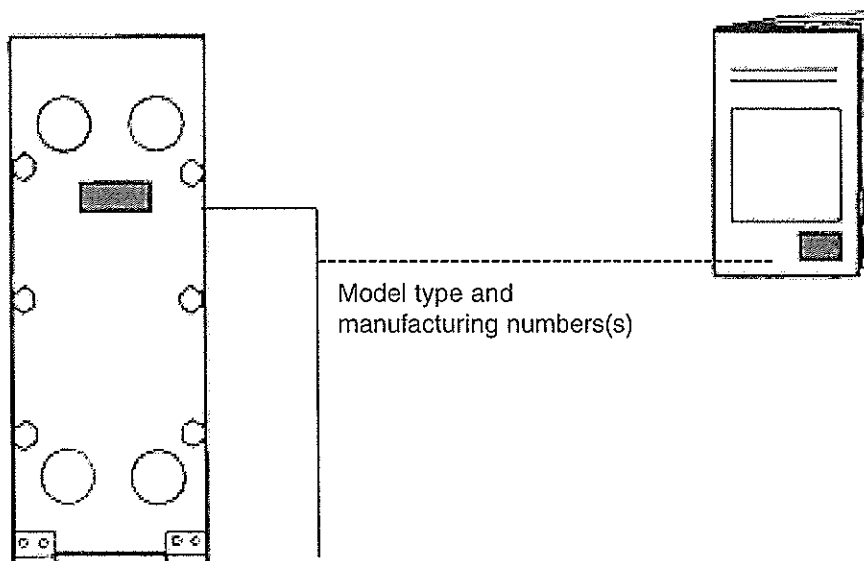
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• Removal and Insertion of plates	6.6
• Closing	6.7, 6.8, 6.9, 6.10, 6.11
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• End Plate II Gaskets For Parallel Flow Units	7.10
• End Plate II Gaskets For Diagonal Flow Units	7.11
FAULT DETECTION	8
• Leakage at Connections or Plates	8.1, 8.2
• Internal Mixing of Media	8.3
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SUPPLEMENTARY PARTS	9
• Partition Plate	9.1
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To our valued customer:

Thank you for purchasing an Alfa Laval Plate Heat Exchanger. As the world's largest manufacturer of Heat Exchangers, we are very proud of our products and services. We value you as our customer and wish to assure your satisfaction. We have prepared this Instruction Manual to assist you with your Alfa Laval Plate Heat Exchanger in various situations. We suggest that you look through it carefully, and, above all, make it readily available to any personnel who may need it for reference.

2

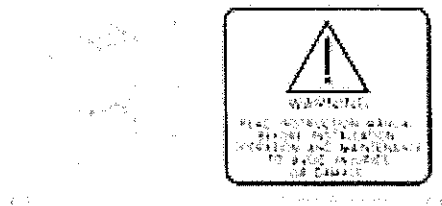
The name plate - and the identification of the equipment



A name plate like the one shown below is fixed to the apparatus as shown above and it gives the following information

NATIONAL BOARD TESTING
CERTIFIED BY
U
W
www.atlulaval.com
NAME 150 150 150 AT 150 F
NAME 150 F 150 150 150 F
SERIAL # 150150 150150
YEAR 150150
MODEL 150150
SPEC 150150 150 F
150 150 150 150 150 150 150 150
150 150 150 150

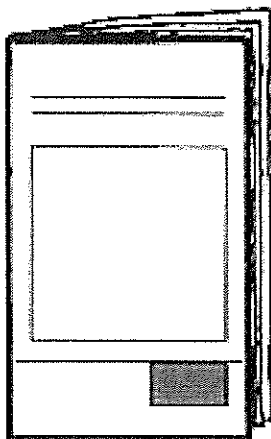
For more information
1-800-249-2171 OR www.glastron.com



2.1

The name plate

- and the identification of the equipment



This instruction manual has been issued for many different models of Alfa Laval *industrial* PHEs. There are separate manuals for *industrial*, *sanitary*, *spiral*, *alfa rex*, *brazed* & *evaporator/condensor* heat exchangers.

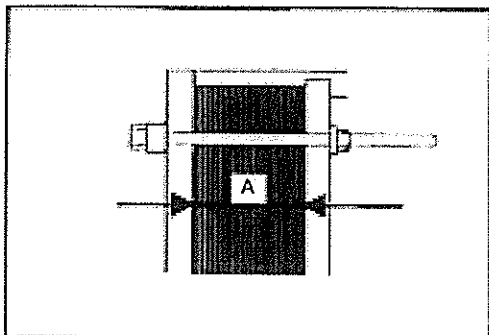
- WHENEVER USING THE MANUAL, CHECK FIRST THAT THE SERIAL NUMBER ON THE FRONT COVER IS IDENTICAL TO THAT ON THE NAME PLATE OF THE EQUIPMENT.
- IN ALL CORRESPONDENCE WITH ALFA LAVAL, PLEASE REFER TO THE MANUFACTURING SERIAL NUMBER, FOR TRUE IDENTIFICATION OF THE EQUIPMENT.
- WHENEVER CONTACTING ALFA LAVAL ABOUT A PART FOR YOUR PLATE HEAT EXCHANGER, BE SURE TO STATE THE MANUFACTURING SERIAL NO.(S), AND MODEL TYPE.

3

General

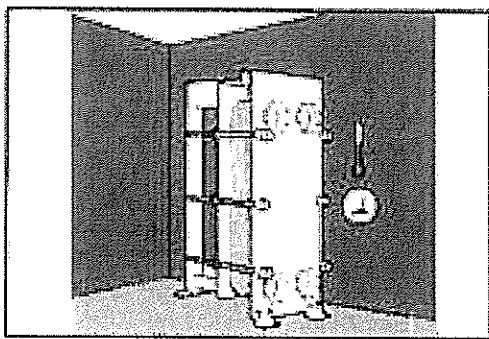
STORAGE

In this section, names of heat exchanger parts are mentioned for the first time. For your information, see Chapters 4A or 4B FUNCTION.



1. Unless otherwise agreed, ALFA LAVAL delivers the plate heat exchanger ready to be put in service upon arrival. This means that the plate package is tightened to its correct measurement A.

Should it be necessary, however, to store the equipment for a longer period (1 month or more) before, certain precautions should be made in order to prevent unnecessary wear of the equipment:

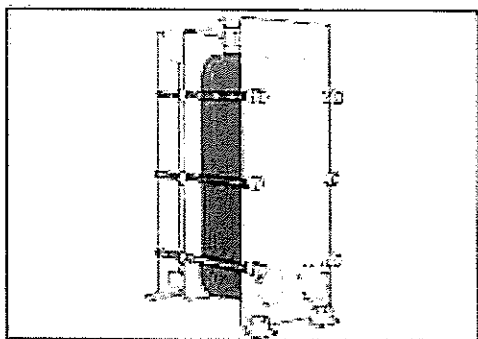


2. Preferably, the heat exchanger should be stored inside, in a room with a temperature around 15 to 20 degrees Celsius (60 to 70 degrees Fahrenheit) and humidity around 70%

There should ABSOLUTELY NOT be any OZONE-PRODUCING equipment in the room, like electric motors or arc-welding equipment, since ozone destroys many rubber materials (cracking).

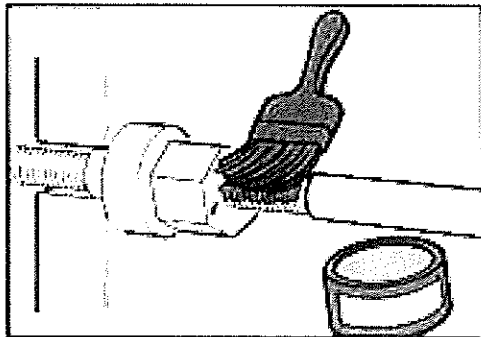
Do not store organic solvents or acids in the room.

Avoid heat or ultraviolet radiation.



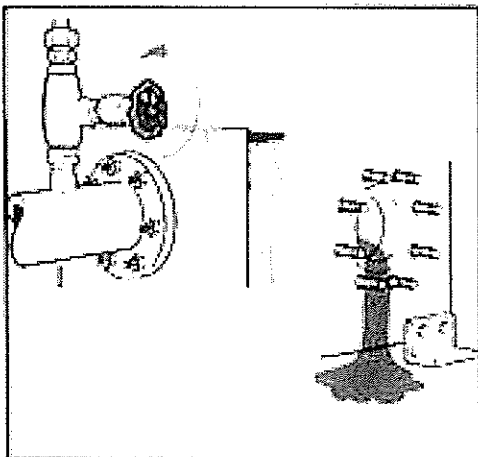
3. Wrapping the PHE with a non-transparent plastic film is a good precaution. Use of transparent film can alter paint color if unit is stored in direct sunlight.

STORAGE



4. The tightening bolts should be well covered with good rust preventing coating, suitable types (LUBRIPLATE FGL-2 or Equivalent) and if not connected to the pipe system, the connections should be covered.

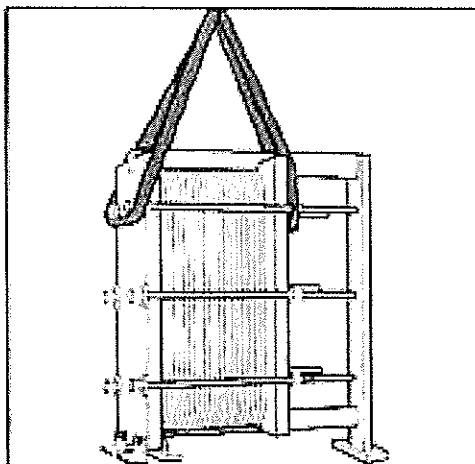
If the heat exchanger must be stored outdoors, the precautions mentioned above should be taken as far as practical. The need for protection against the climate etc. is of course even more important in this case.



5. If for any reason the heat exchanger is removed from service for a long period, it is advantageous to follow the advice above, even if the equipment is not moved from the location.

The heat exchanger should be VENTED AND DRAINED, and depending on the media processed, it is recommended to RINSE AND DRY it, before it is stored.

LIFTING



1. Whenever the heat exchanger is lifted, straps should be placed around tightening bolts on both sides of the unit, as shown in picture. If lifting lugs or lifting eyes are provided, always use chains or lifting cables rated above the published weight of the heat exchanger.

NEVER LIFT BY THE CONNECTIONS OR THE STUDS AROUND THEM!

LIFTING CONTINUED

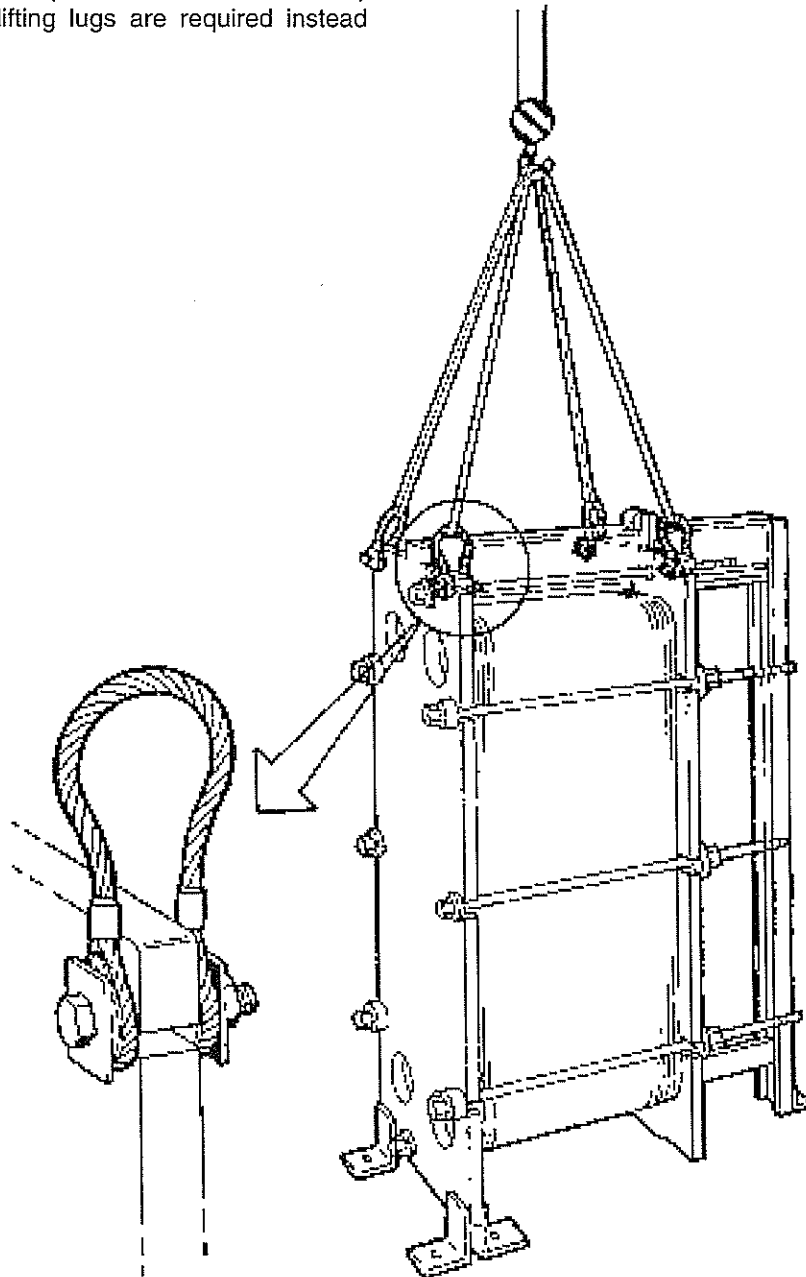
If Lifting Lugs are provided

If you are to lift the heat exchanger itself, straps should be used. They should be placed as shown on the picture.

On smaller units (4" connected size smaller) typically two lifting lugs are required instead of four.

WARNING!

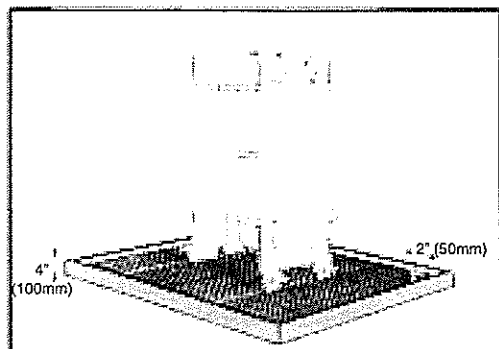
Never lift by the connections or the studs around them.



General

FOUNDATIONS.

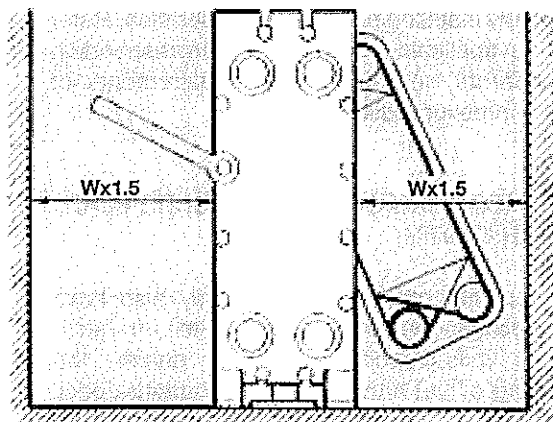
All information necessary for the preparation of the foundation appears on the data sheet provided by ALFA LAVAL.



In some cases (installation on board a ship, when processing corrosive liquids, etc.) it may be practical to place the heat exchanger in a DRAINAGE BOX (with capacity for the total volume of the heat exchanger). The outlet of the drainage box should be generously dimensioned, not less than (2") 50 mm diameter.

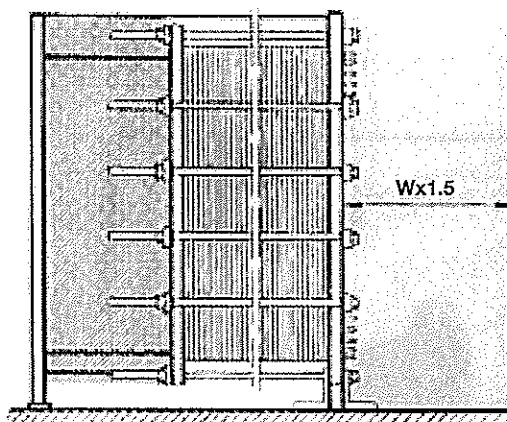
INSTALLATION.

BEFORE connecting any piping to the heat exchanger, MAKE SURE THAT ALL FOREIGN OBJECTS HAVE BEEN FLUSHED OUT OF THE SYSTEM!



PLEASE OBSERVE THAT

The measurements given in the picture above are recommended by ALFA LAVAL, it is necessary to leave free space around the equipment, to provide access and make future service possible. Except for a place to put the plates, if removed from the heat exchanger, NO FURTHER SPACE is required for servicing the PHE.



PLEASE OBSERVE THAT

The measurements given in the picture are recommended by ALFA LAVAL, to provide reasonably good working conditions during installation of the heat exchanger as well as for future maintenance and service. If floor space is restricted, the dimensions suggested can be reduced. It is left to the purchaser to decide just how much access space is required.



This field should be kept free from fixed installations.



Recommended free space for opening and closing.

PIPES

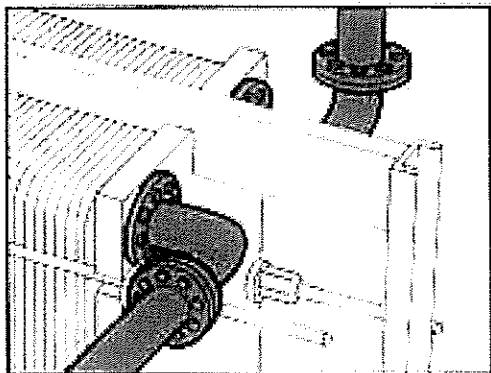
Always ensure that no measurable stress is placed on the heat exchanger by the piping system.

SHUT OFF VALVES

To enable the heat exchanger to be opened when necessary shut off valves should be provided on all connections.

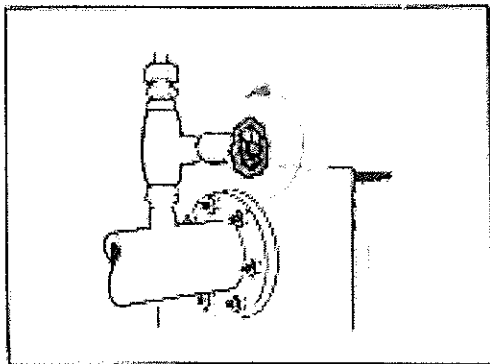
PRESSURE RELIEF DEVICES

It is the responsibility of the user to ensure that the required pressure relief devices are properly installed prior to initial operation. Refer to the applicable Code(s) and corresponding Standard(s) for proper size requirements of these pressure relief devices.



CONNECTIONS ON THE PRESSURE PLATE (REAR COVER)

Some plate heat exchangers may also have connections on the pressure plate. In such cases, it is important to check against the drawing or the name plate that the plate pack has been tightened to the right measurement before the piping is connected.



Whenever piping is connected to the pressure plate, a short 90° spool piece shall be installed between the heat exchanger and the piping. These should be directed upwards or sideways. This simplifies pressure plate removal during servicing.

Venting of both sides of the heat exchanger must be provided. This is important and enables air to be drawn from the system during start-up. It also enables air or gas to be removed during operation, and it enables faster drainage.

Special Loose Flange Connections

Loose Flanges are provided on certain model types due to interference. When provided these flanges shall be incorporated into the piping.

MODELS WITH BOTH "S" AND "T" PORT CONNECTIONS

M6-FD, M6-MFD, M6-MWFD, M10-BFD, M10-MFD, M10-BWFD, M10-BDFD, M20-MFD*, M20-MWFD*

MODEL TYPES WITH LOOSE FLANGE ON T PORT CONNECTIONS ONLY:

M6-FG, M6-MFG, M6-MWFG, M10-BFG, M10-MFG, M10-BWFG, M10-BDFG, V28-FD*, V45-FD*, M20-MFG, M20-MWFG

* Loose flange only when design pressures above 230 psi.

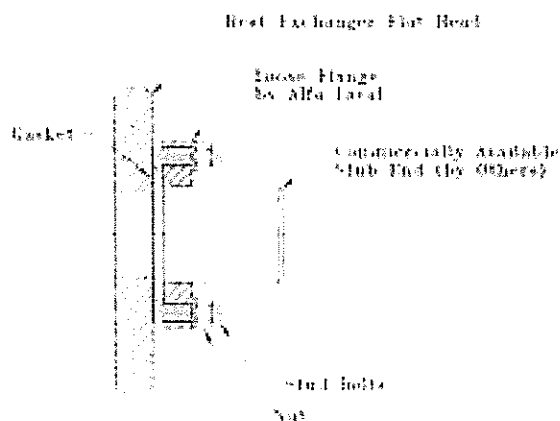
Notes:

- 1) Sports connections on these model types utilized industry standard flanges.
- 2) Not all exchangers require T port connections.

PIPING CONNECTION

The loose flange is connected to piping by use of a commercially available stub end of same material as the piping.

The stub end is installed as shown and then butt weld to the piping.



4A

LIST OF PARALLEL FLOW UNITS

“A” SERIES UNITS:

AM10-FG; AM10-FS

A15-BFL; A15-BFG; A15-BFD; A15-BWFG; A15-BWFD

A20-BFL; A20-BFG; A20-BFD

AM20-FG; AM20-BFG; AM20-WFG; AM20-SFG; AM20-DWFG

AK20-FG; AK20-FD; T200-FG; T200-FD

AX30-BFG; AX30-BFD; AX30-BWFG; AX30-BWFD

A35-HA

“M” SERIES UNITS:

M3-VG

M6-FG; M6-FD; M6-MFG; M6-MFD; M6-MWFD/FG/FDR/FGR

M10-BFM; M10-BFG; M10-BFD; M10-MFG; M10-MFD;

M10-BWFG; M10-BWFD; M10-BWFGR, M10-BWFDR

M15-BFG; M15-BFD; M15-BFS; M15-MFG;

M15-MFD; M15-MFS; MK15-BWFD; MK15-BWFG

M20-MFG; M20-MFM; M20-MFD; M20-MWFG; M20-MWFD

M30-FM; M30-FG; M30-FD

MA30-FD; MA30-FG; MA30-WFG; MA30-WFD

MX25-BFG; MX25-BFD; MX25-BFS

EC500-WTFE; EC500-WTFL

“V” SERIES UNITS:

V8-VG, V13-FG, V13-FD, V20-FG, V20-FD

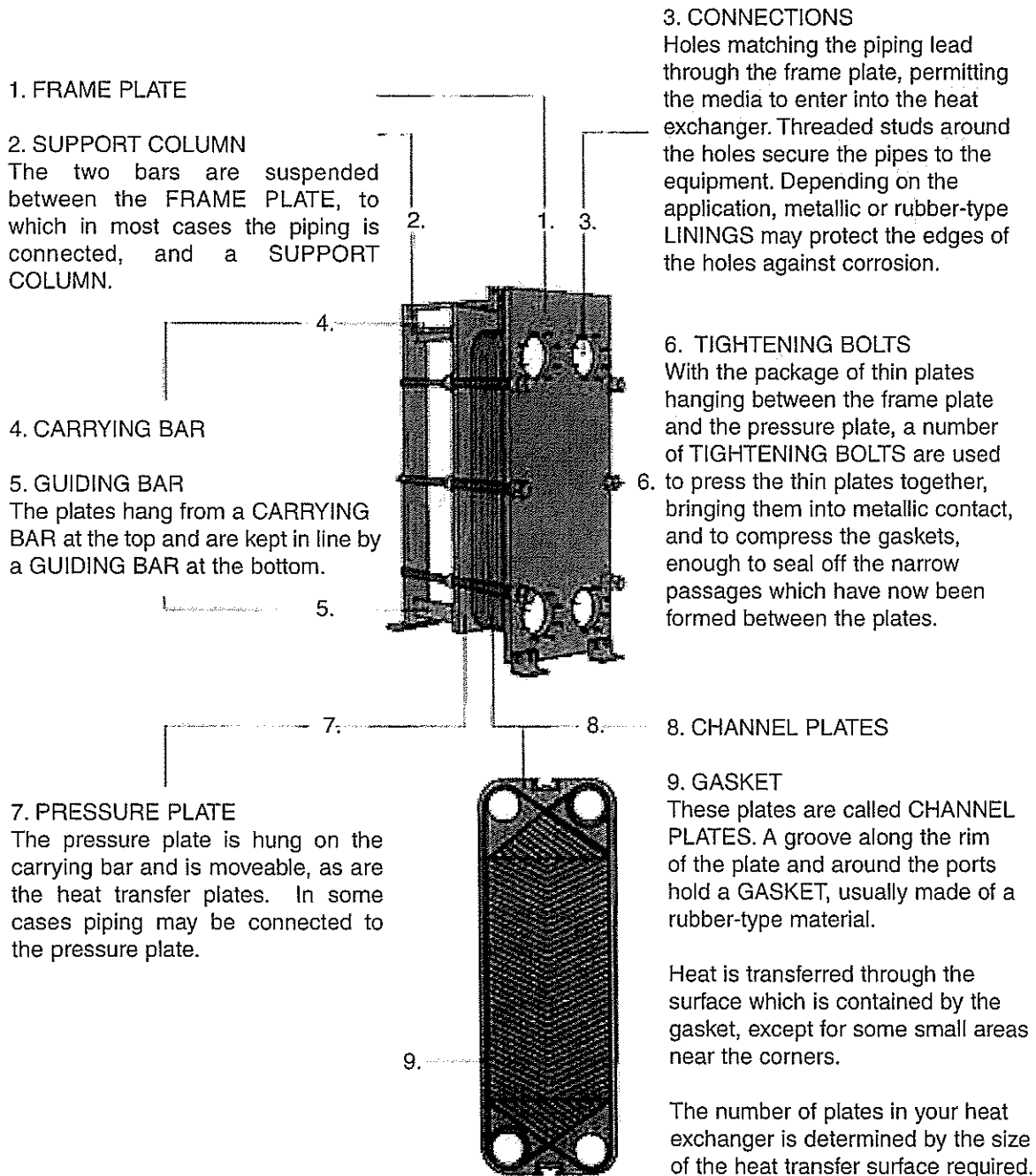
PARALLEL FLOW UNITS

4A

Function

THE MAIN COMPONENTS OF THE PLATE HEAT EXCHANGER AND THEIR FUNCTIONS.

In ALFA LAVAL Plate Heat Exchangers, heat is transferred from one medium to another through thin metal plates which have been pressed into a special pattern.

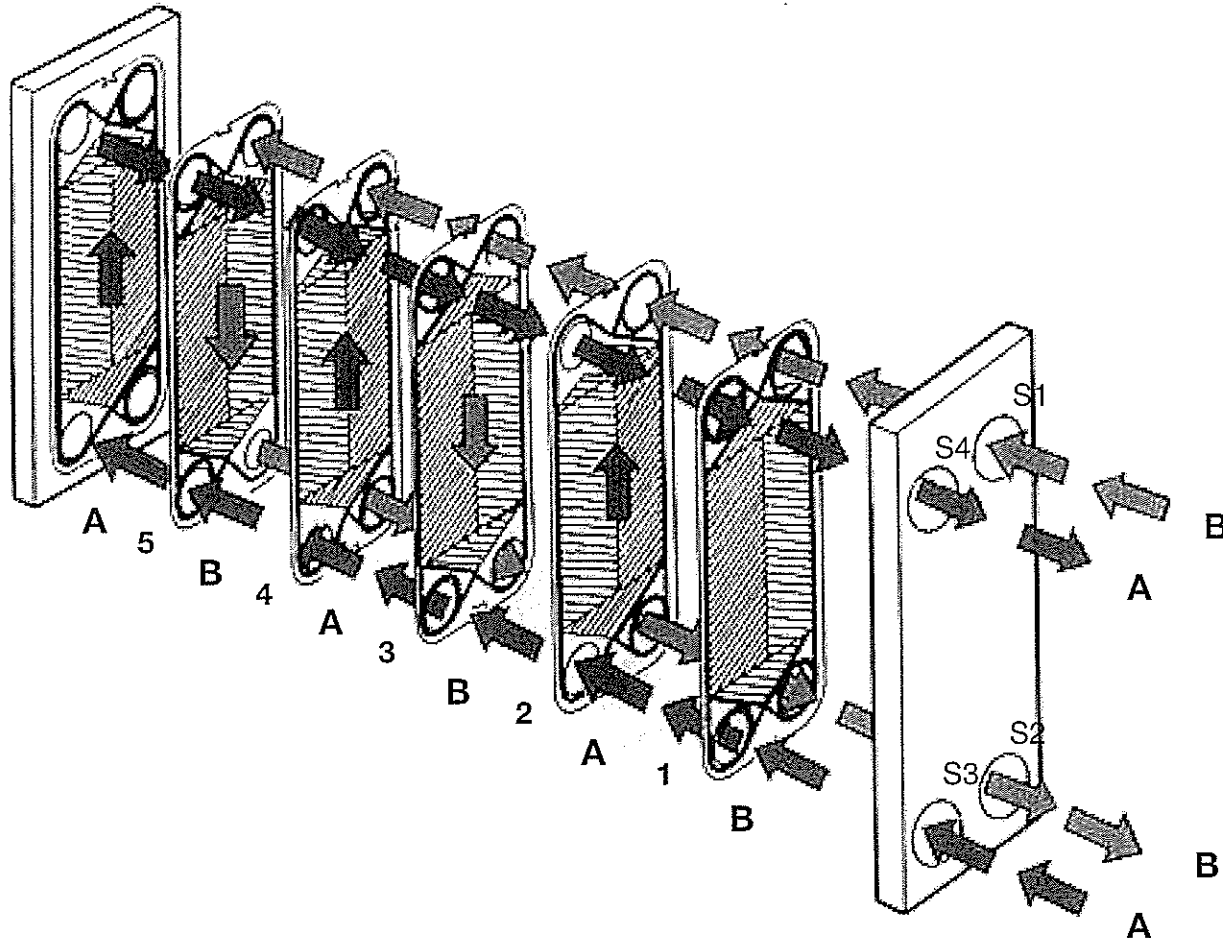


4A.2

4A

PARALLEL FLOW UNITS

How it works



When a package of plates are pressed together, the holes at the corners form continuous tunnels or manifolds, leading the media (which participate in the heat transfer process) from the inlets into the plate pack, where they are distributed in the narrow passages between the plates.

Because of the gasket arrangement on the plates, and the placing of "A" and "B" plates alternately, the two liquids enter alternate passages, e.g. the warm liquid between even number passages, and cold liquid between odd number passages.

Thus the media are separated by a thin metal wall. In most cases the liquids flow in opposite directions.

During the passage through the equipment, the warmer medium will give some of its heat energy to the thin wall, which instantly loses it again to the colder medium on the other side.

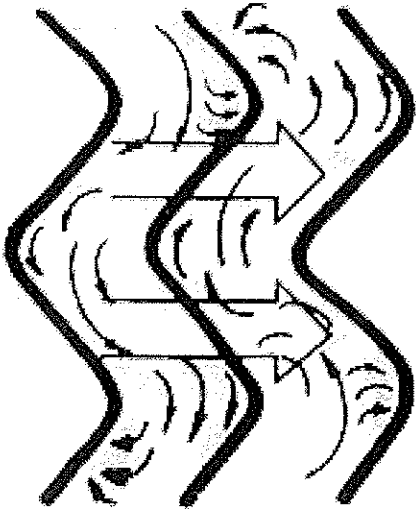
The warmer medium drops in temperature, while the colder one is heated up.

Finally, the media are led into similar hole-tunnels at the other end of the plates and discharged from the heat exchanger.

PARALLEL FLOW UNITS

4A

Heat transfer



The purpose of the equipment is to transfer heat from one medium to another. Heat passes very easily through the thin wall separating the two media.

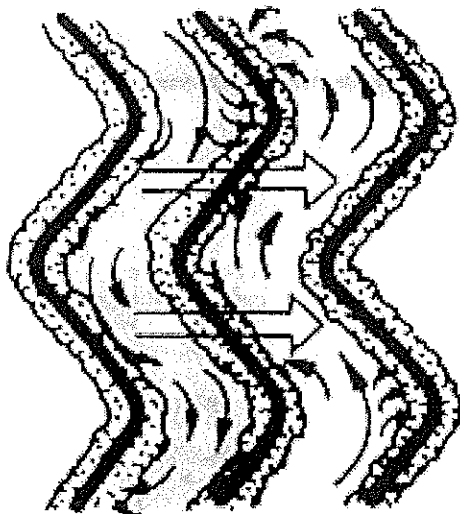
The novel pattern into which the plate material has been formed not only gives strength and rigidity, but greatly increases the rate of heat transfer from the warmer medium to the metal wall and from the wall to the other medium.

This high heat flow through the walls can be seriously reduced by the formation of deposits of various kinds on the wall surfaces.

The pattern of corrugation on Alfa Laval plates mentioned above induces highly turbulent flow. The turbulence gives strong resistance to the formation of deposits on the plate surface; however, it cannot always eliminate fouling.

The deposits may increase the total "wall thickness" substantially, and they consist of materials that have a much lower thermal conductivity than the metal plate. Consequently a layer of deposits can severely reduce the overall heat transfer rate.

The deposits will be considered in the chapter on MAINTENANCE and CLEANING. At this point we will only establish that this fouling is unwanted and can under certain circumstances, be harmful to the heat exchanger because corrosion may occur under the deposits.



Pressure drop

Pressure drops are wasted energy.

All pipe systems and equipment included in them offer resistance to media flowing through them.

Some pressure drop is unavoidable, but for a given PHE it should be kept as close as possible to the designed value.

The formation of deposits on the heat transfer surfaces instantly leads to a reduction of the free space between the plates. This means that more energy is needed to get the desired flow through the equipment.

It is clear that the fouling of the surfaces is undesirable.

Larger particles and fibers may also be drawn into the heat exchanger and clog the passage ways if strainers or other means of protection have not been provided for.

A reduced ability by the heat exchanger to hold the desired temperatures, in combination with an increased pressure drop on any of the media, indicates that fouling or clogging is taking place.

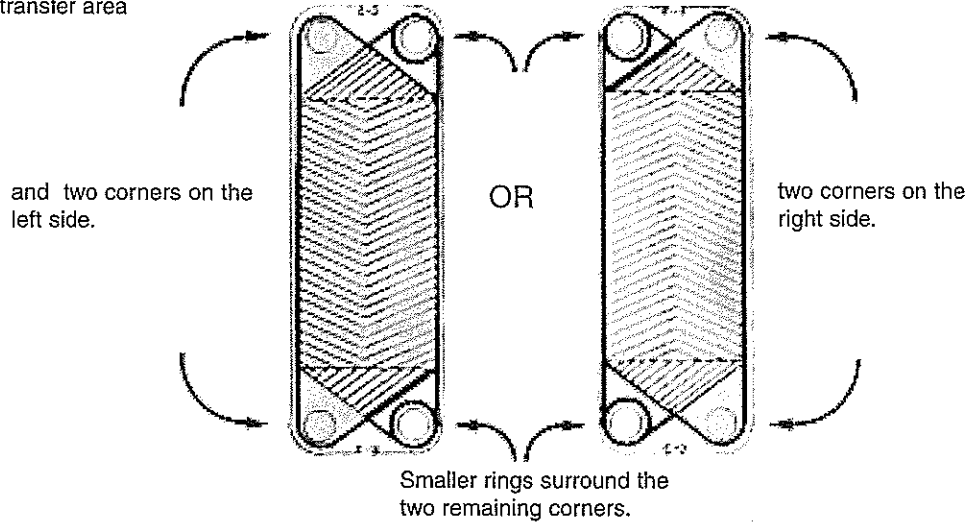
For corrective action, see MAINTENANCE and CLEANING.

4A.4

4A

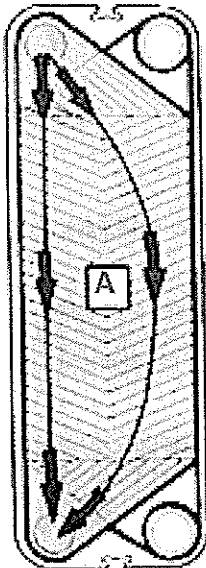
PARALLEL FLOW UNITS

Studying the pictures, you will observe that on a plate hanging vertically, the gasket rests in a groove which includes the heat transfer area

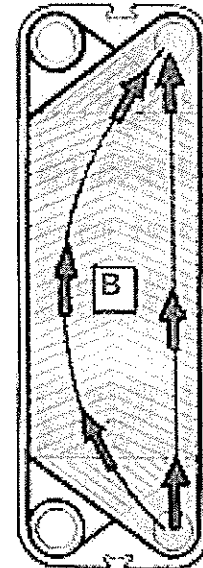
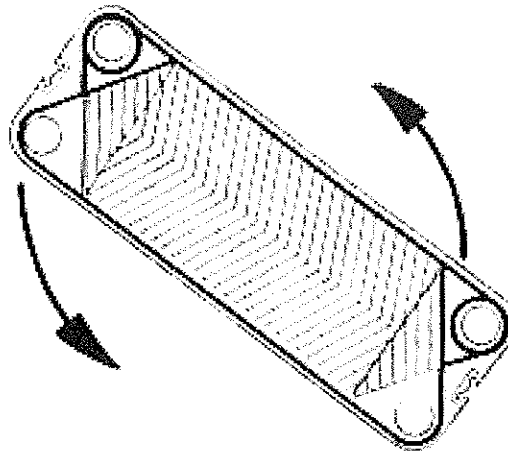


We decide that we will name the plates after these two situations.

An A-plate is a plate hanging with the chevron pointing downwards.



A B-plate is a plate hanging with the chevron pointing upwards.

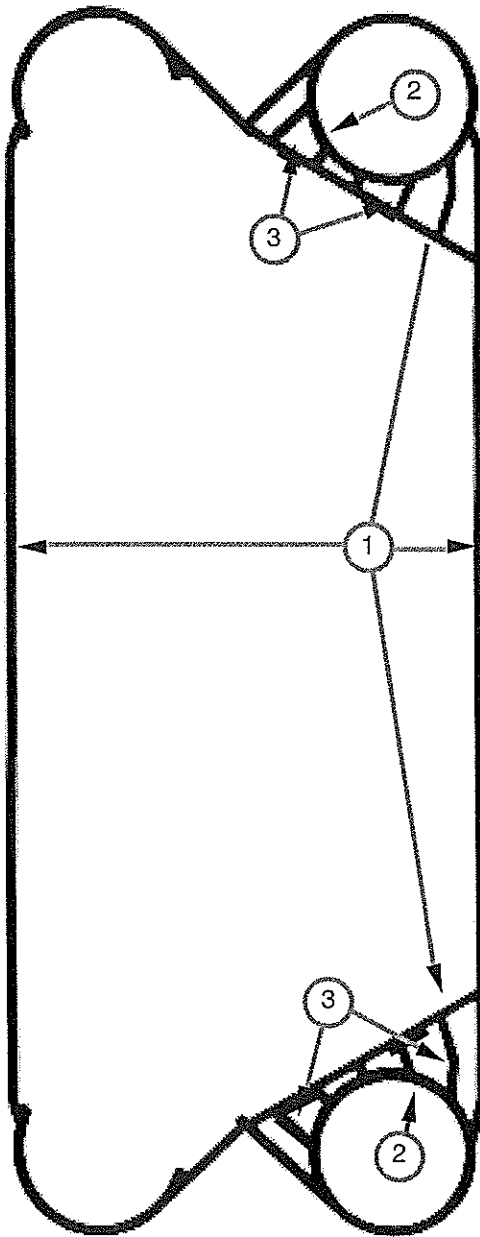


If we turn an A-plate upside down we will have a B-plate:

4A.5

Gaskets

The GASKET is molded in one piece. The material is normally an elastomer, selected to suit the actual combination of temperature, chemical environment and possible other conditions that may be present.



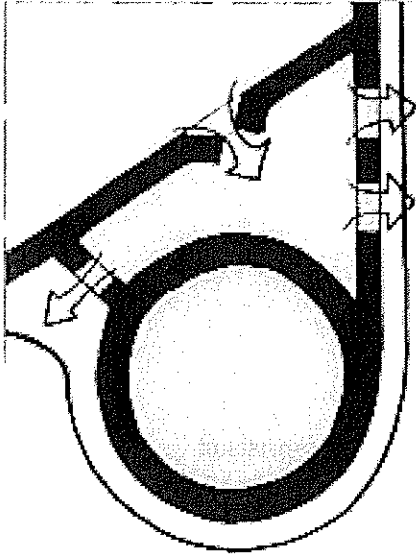
The one-piece gasket consists of:

1. One field gasket
2. Two ring gaskets
3. Links

The field gasket is by far the larger part containing the whole heat transfer area and the two corners connected to it. The ring gaskets seal off the remaining two corners.

These three pieces are held together by a few short links, which have no sealing function at all. Their purpose is simply to tie the pieces together and to add some support in certain areas. On some plate heat exchangers, the gasket is held in place on the plate by means of a suitable cement or glue.

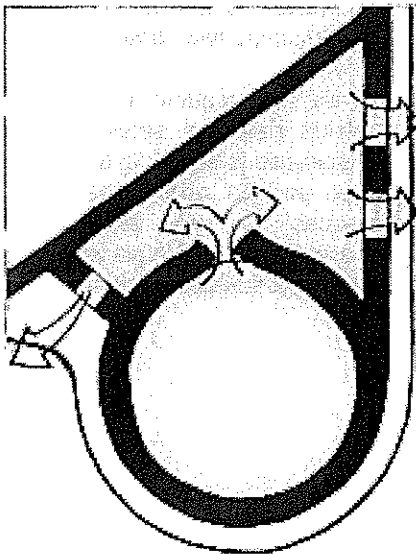
Gaskets



As already demonstrated, the two media are effectively kept apart by the ring and field gaskets. To prevent intermixing of the media in the corner areas where field and ring gaskets are very close to each other, the link pieces have a number of slots which opens the area between the field and ring gaskets to atmosphere. Any leakage of media across either gasket will escape from the heat exchanger through the slots.

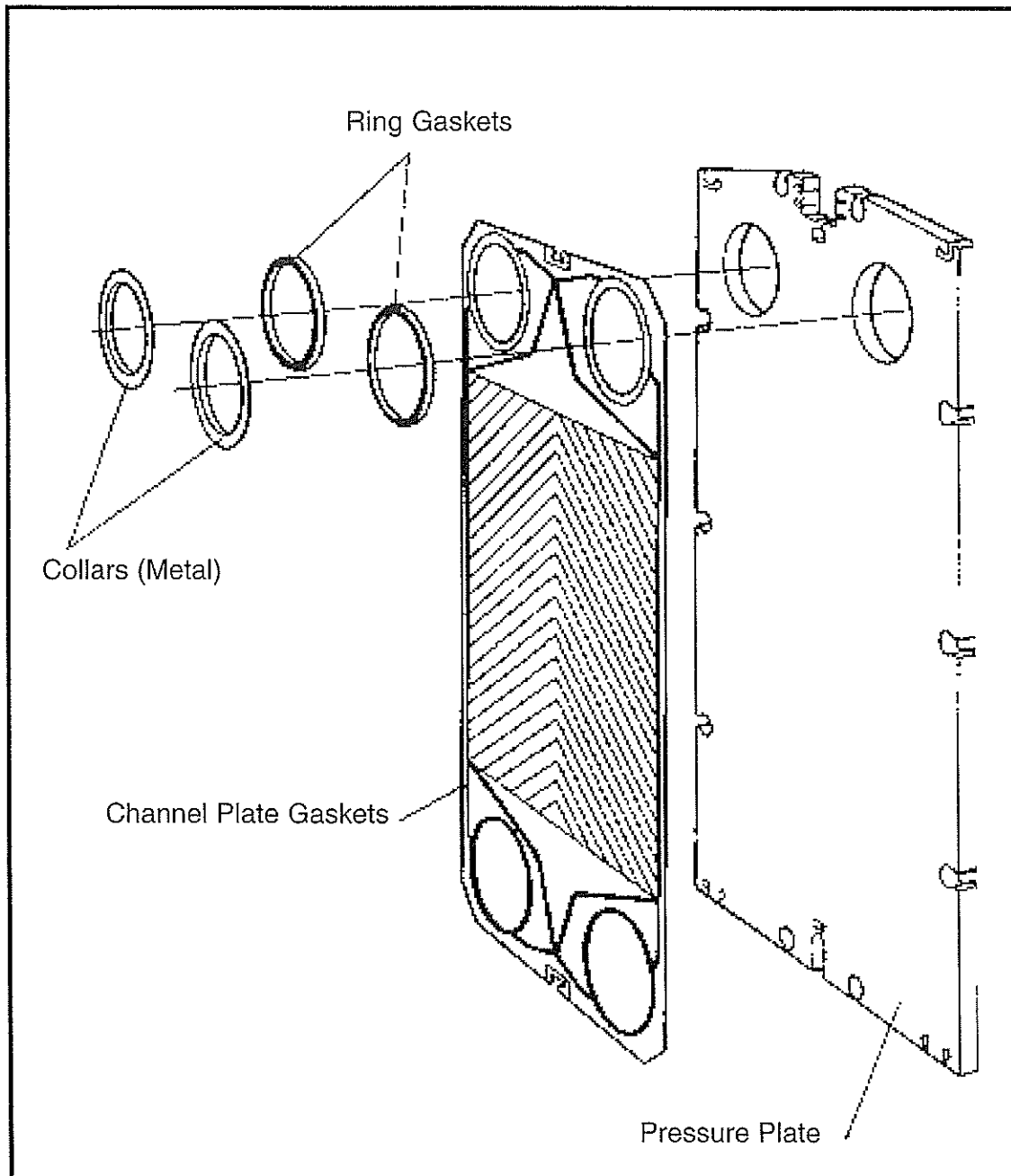
It is important that these openings are kept clear. If they are not, there is a risk that should a leak occur in that region of the plate, there might be a local pressure build-up, which could allow one medium to mix with the other.

Care should be taken not to cut or scratch the gaskets while handling plates.



TRANSITION PLATE

M30, MX25, A20-B, AM20, AK20, T200, A15-B, M15, M10, M6



4B List of Diagonal Flow Units

"A" SERIES UNITS:

A10-BFG; A10-BFD

AX35-FG

A45-FG

"P" SERIES UNITS:

P2-FG; P2-VLCH; P2-DWFG

P3-E; P3-EH

"M" SERIES UNITS:

M3-XVG

"V" SERIES UNITS:

V28-FG, V28-FD, V45-FG, V45-FD, V110-FG, V110-FD,
V170-FG, V170-FD, V280-FG, V280-FD

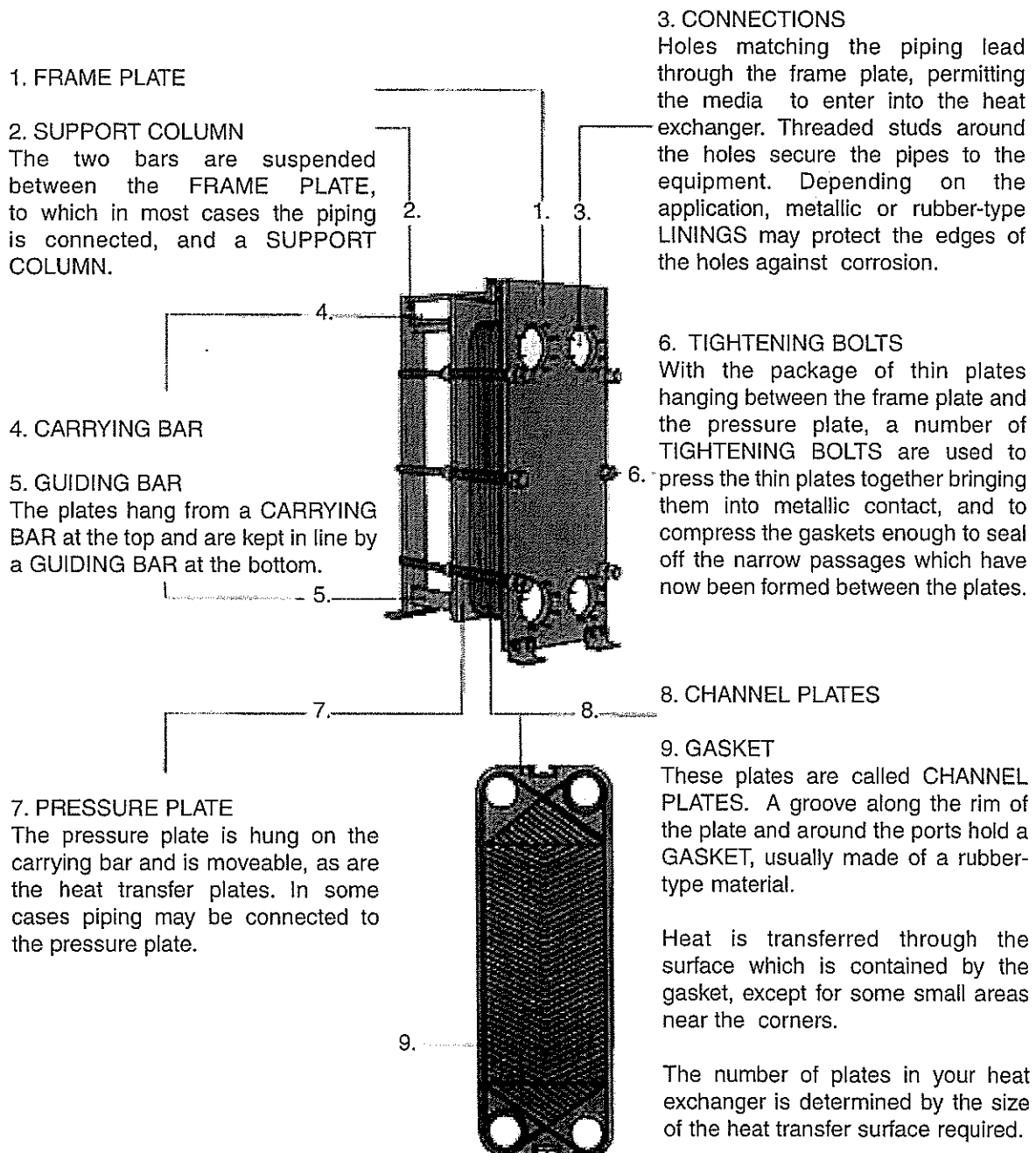
DIAGONAL FLOW UNITS

4B

Function

THE MAIN COMPONENTS OF THE PLATE HEAT EXCHANGER AND THEIR FUNCTIONS.

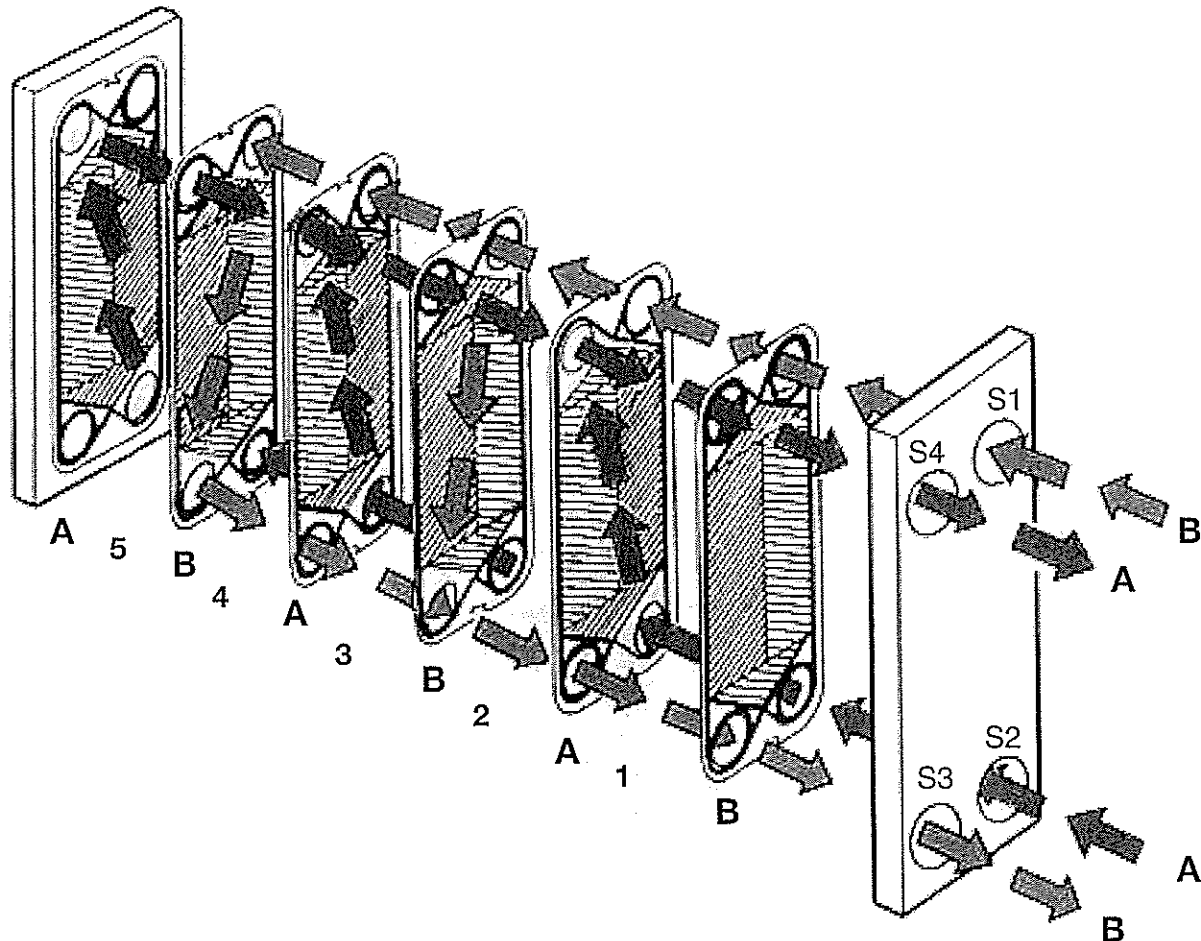
In ALFA LAVAL Plate Heat Exchangers, heat is transferred from one medium to another through thin metal plates which have been pressed into a special pattern.



4B

DIAGONAL FLOW UNITS

How it works



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Thus the media are separated by a thin metal wall. In most cases the liquids flow in opposite directions.

During the passage through the PHE, the warmer medium will give some of its heat energy to the thin wall, which instantly loses it again to the colder medium on the other side.

The warmer medium drops in temperature, while the colder one is heated up.

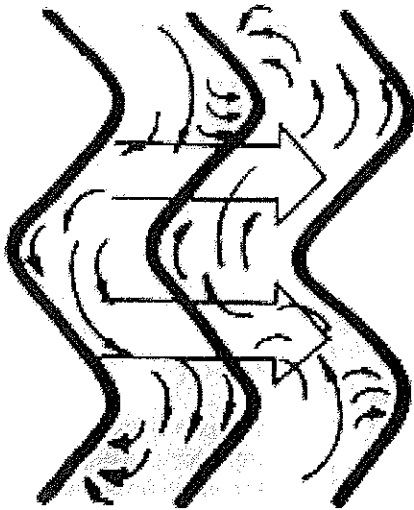
Finally, the media are led into similar hole-tunnels at the other end of the plates and discharged from the heat exchanger.

4B.3

DIAGONAL FLOW UNITS

4B

Heat transfer

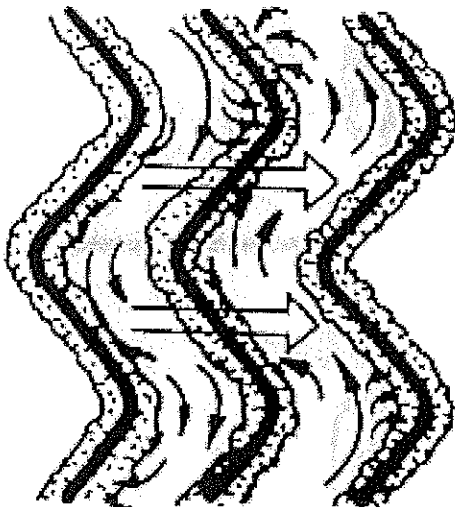


The purpose of the equipment is to transfer heat from one medium to another, and heat passes very easily through the thin wall separating the two media.

The novel pattern into which the plate material has been formed not only gives strength and rigidity, but greatly increases the rate of heat transfer from the warmer medium to the metal wall and from the wall to the other medium.

This high heat flow through the walls can be seriously reduced by the formation of deposits of various kinds on the wall surfaces.

The pattern of corrugation on Alfa Laval plates mentioned above induces highly turbulent flow. The turbulence gives strong resistance to the formation of deposits on the plate surface; however, it cannot always eliminate fouling.



The deposits may increase the total "wall thickness" substantially, and they consist of materials that have a much lower thermal conductivity than the metal plate. Consequently a layer of deposits can severely reduce the overall heat transfer rate.

The deposits will be considered in the chapter on MAINTENANCE and CLEANING. At this point we will only establish that this fouling is unwanted and can under certain circumstances, be harmful to the heat exchanger because corrosion may occur under the deposits.

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Some pressure drop is unavoidable, but for a given PHE it should be kept as close as possible to the designed value.

The formation of deposits on the heat transfer surfaces instantly leads to a reduction of the free space between the plates. This means that more energy is needed to get the desired flow through the equipment.

It is clear that the fouling of the surfaces is undesirable.

Larger particles and fibers may also be drawn into the heat exchanger and clog the passage ways if strainers or other means of protection have not been provided for.

A reduced ability by the heat exchanger to hold the desired temperatures, in combination with an increased pressure drop on any of the media, indicates that fouling or clogging is taking place.

For corrective action, see MAINTENANCE and CLEANING.

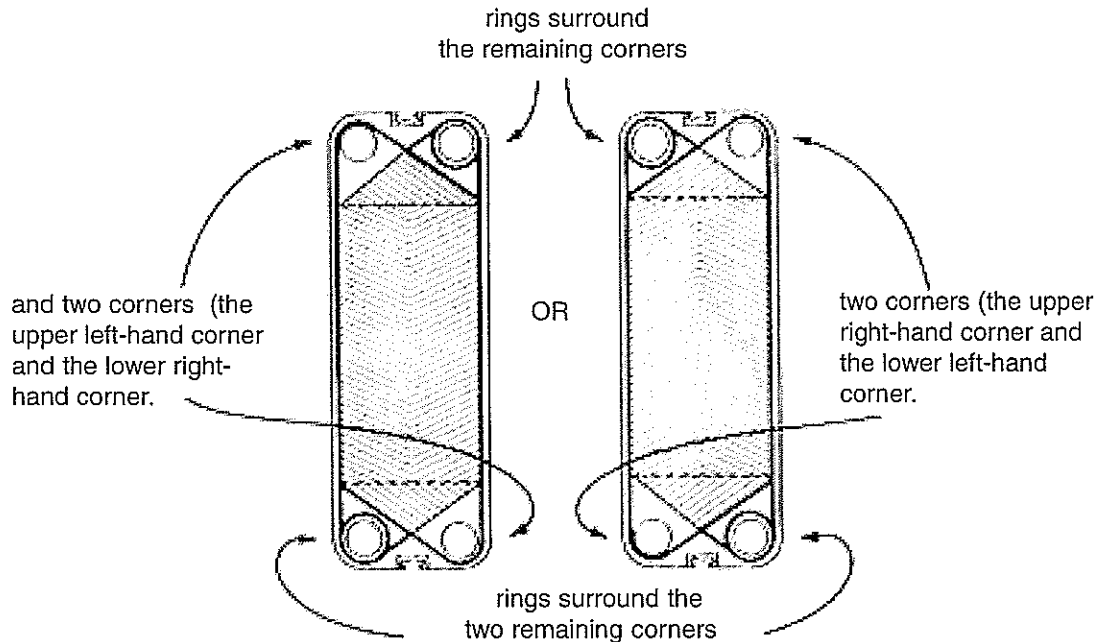
4B.4

4B

DIAGONAL FLOW UNITS

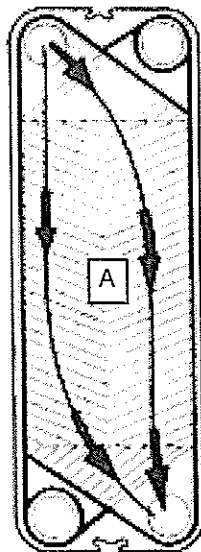
Plates

Studying the pictures, you will observe that on a plate hanging vertically, the gasket rests in a groove which includes the heat transfer area

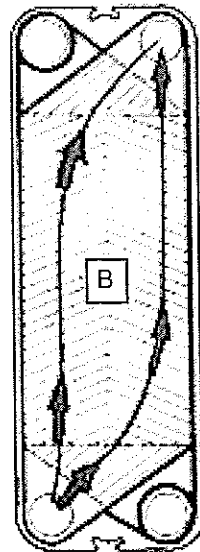


Depending on which two corners are included with the heat transfer area, the plate is called an A- or a B-Plate.

An A-plate is a plate hanging with the chevron pointing downwards.



A B-plate is a plate hanging with the chevron pointing upwards.

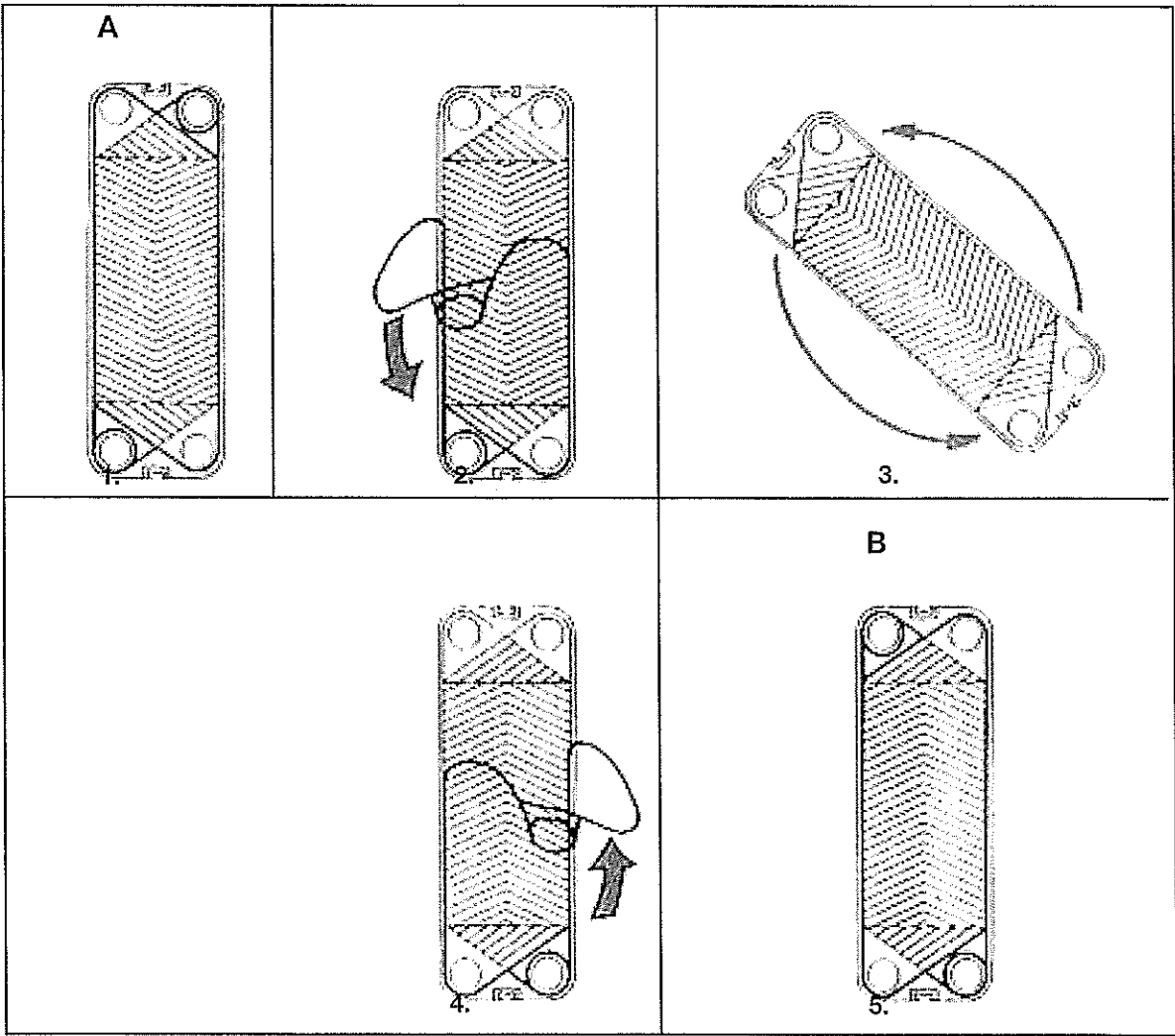


DIAGONAL FLOW UNITS

4B

Plates

We can make a B-Plate from an A-plate or the opposite, by changing the gasket and turning the plate upside down.

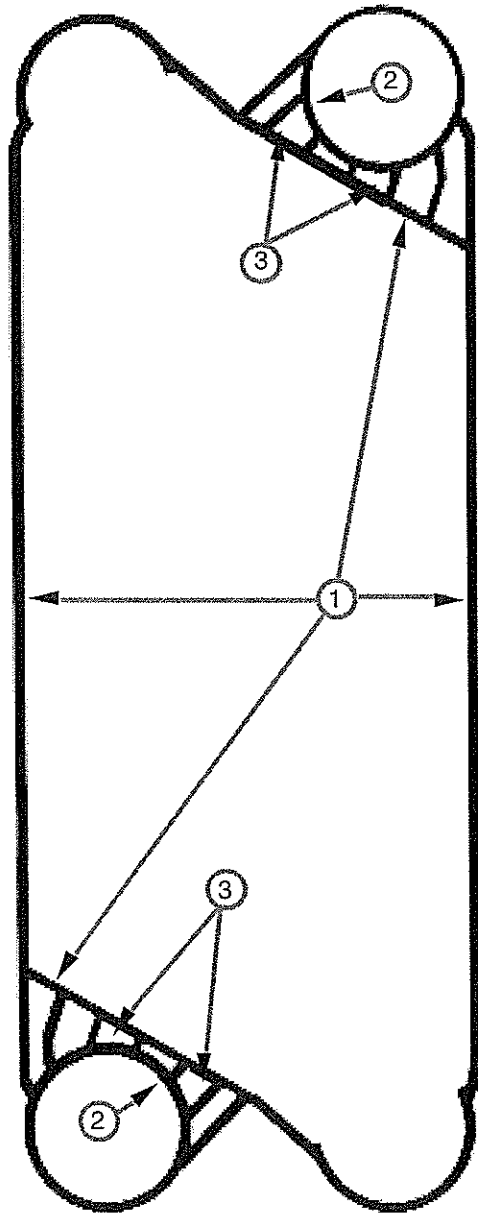


4B

DIAGONAL FLOW UNITS

Gaskets

The GASKET is molded in one piece. The material is normally an elastomer, selected to suit the actual combination of temperature, chemical environment and possible other conditions that may be present.



The one-piece gasket consists of:

1. One field gasket
2. Two ring gaskets
3. Links

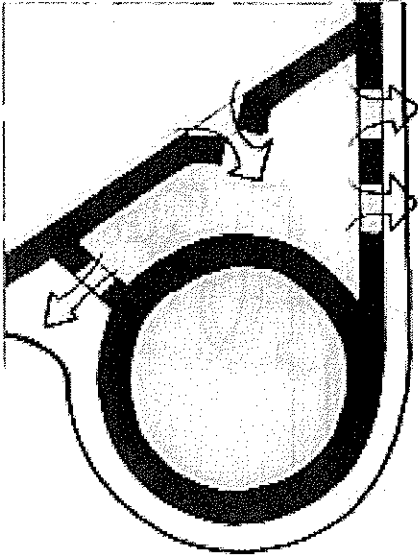
The field gasket is by far the larger part containing the whole heat transfer area and the two corners connected to it. The ring gaskets seal off the remaining two corners.

These three pieces are held together by a few short links, which have no sealing function at all. Their purpose is simply to tie the pieces together and to add some support in certain areas. On some plate heat exchangers, the gasket is held in place on the plate by means of a suitable cement or glue.

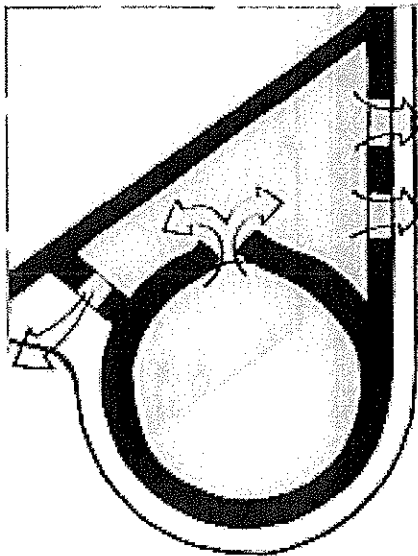
DIAGONAL FLOW UNITS

4B

Gaskets



As already demonstrated, the two media are effectively kept apart by the ring and field gaskets. To prevent intermixing of the media in the corner areas where field and ring gaskets are very close to each other, the link pieces have a number of slots which open the area between the field and ring gaskets to atmosphere. Any leakage of media across either gasket will escape from the heat exchanger through these slots.



It is important that these openings are kept clear. If they are not, there is a risk that should a leak occur in that region of the plate, there might be a local pressure build-up, which could allow one medium to mix with the other.

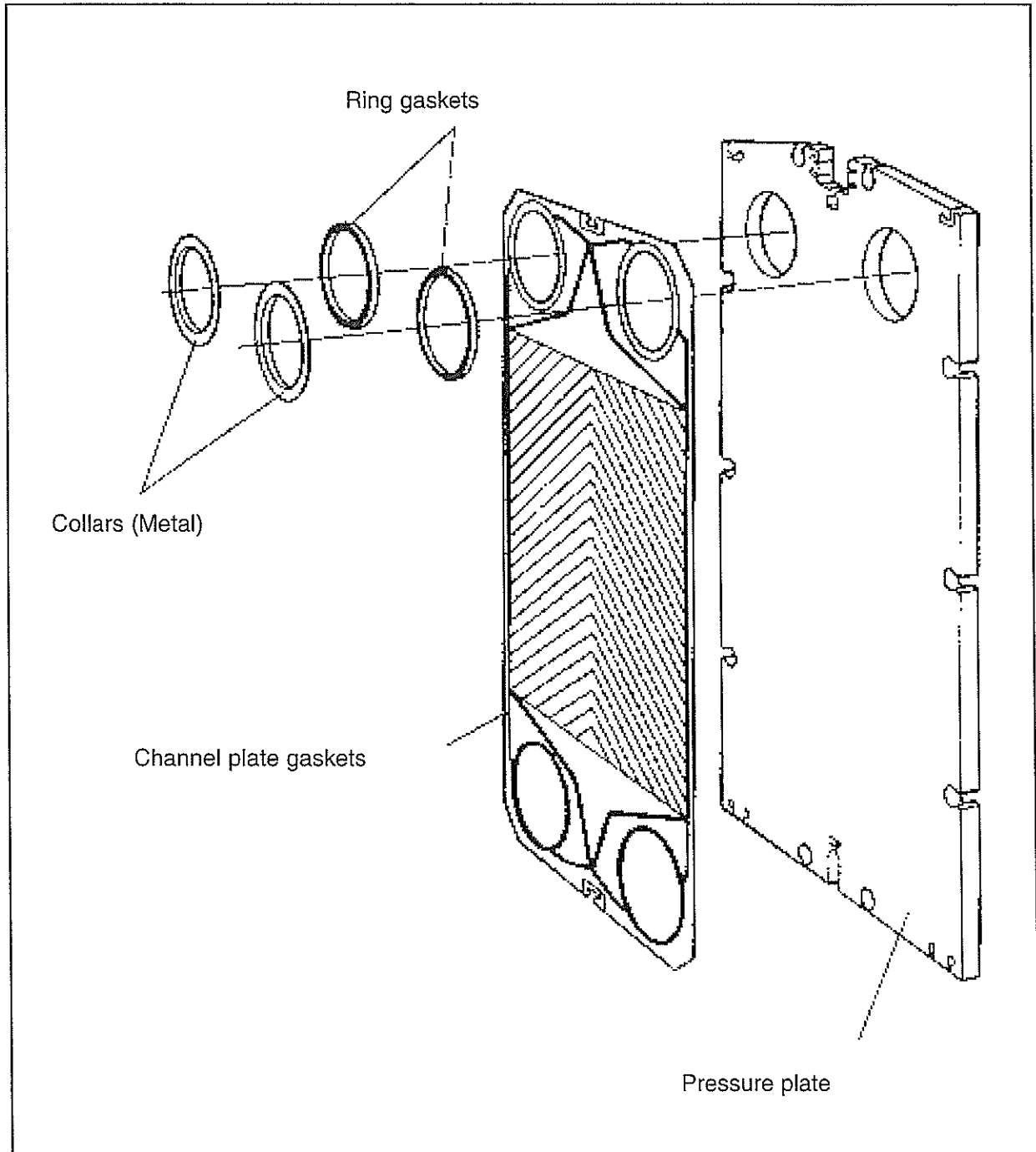
Care should be taken not to cut or scratch the gaskets while handling plates.

4B

DIAGONAL FLOW UNITS

TRANSITION PLATE

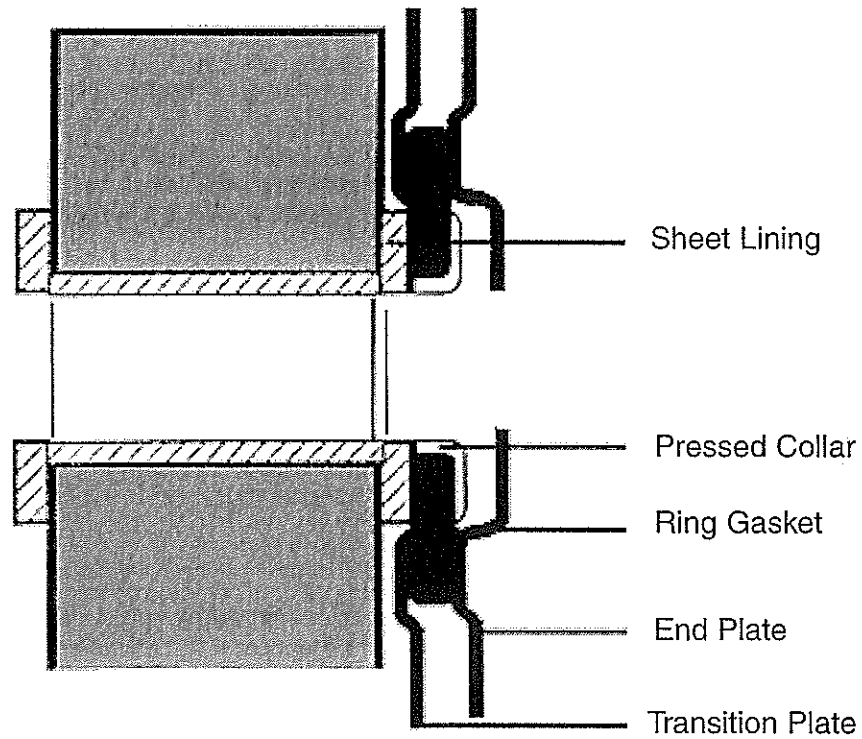
M30, MX25, A20-B, AM20, AK20, T200, A15-B, M15, M10, M6



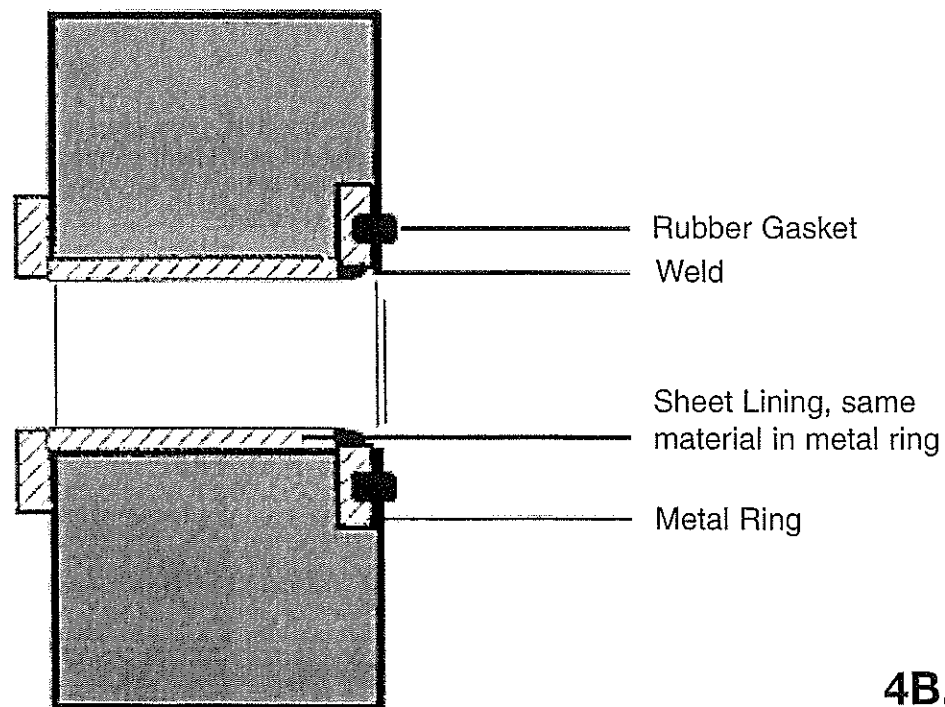
DIAGONAL FLOW UNITS

4B

NON MACHINED PRESSURE PLATE



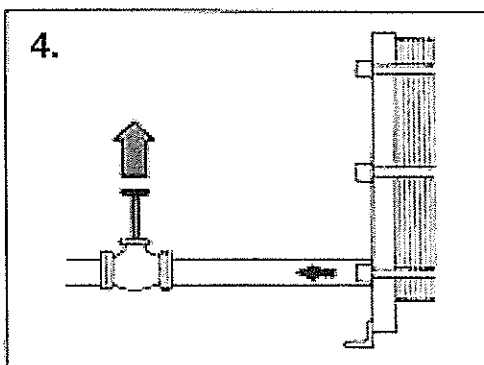
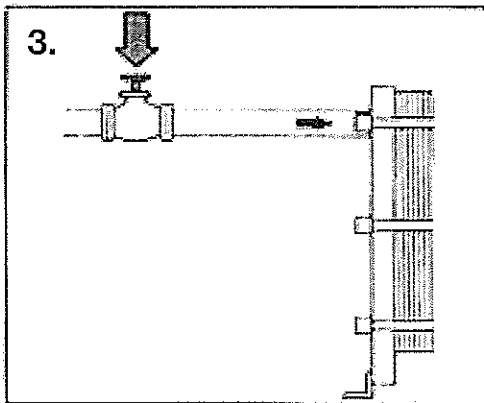
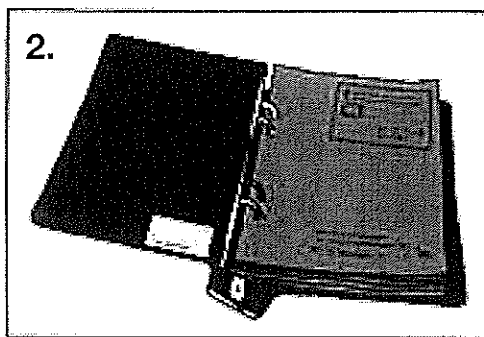
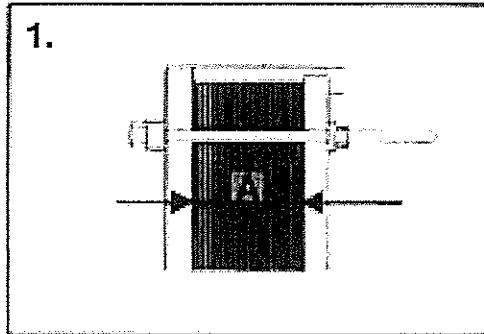
MACHINED PRESSURE PLATE (AX30, AM20 AND OBSOLETE FRAMES)



4B.11

5

Operation



START UP

1. BEFORE STARTING UP FOR THE FIRST TIME OR AFTER A LONG TIME IN STORAGE: MAKE SURE THAT THE PLATE PACK IS COMPRESSED TO THE CORRECT MEASUREMENT A! Check with the Drawing or Nameplate, which is provided with each heat exchanger.

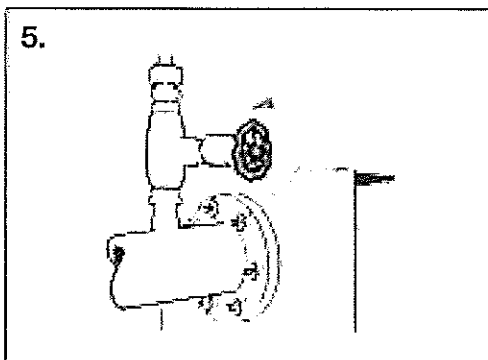
It is very important that the system to which the heat exchanger is connected, is protected against sudden and extreme variations of temperature and pressure. This is not only for the heat exchanger but also for the pipe system itself and every piece of equipment included in it.

This should be kept in mind whenever a maneuver is to be carried out, including starting up of the pumps in the system.

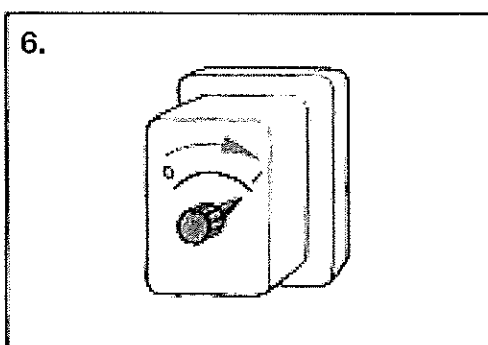
2. Before starting any pump, check whether instructions exist, telling you which pump should be started first.
3. Check that the valve between the pump and the equipment, controlling the flow rate of the system which you are about to start up is closed.
4. Check that the valve at the exit, if there is one, is fully open.

Operation

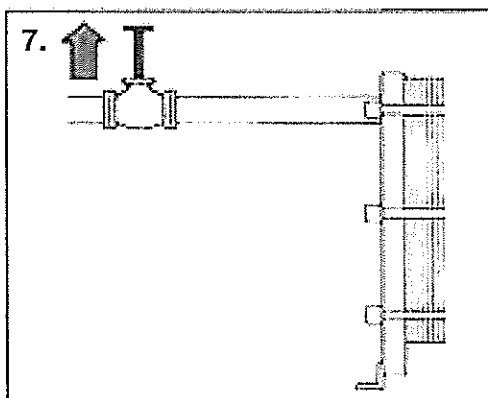
5



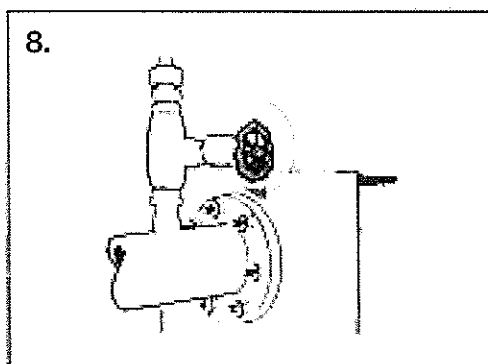
5. Open the vent.



6. Start the Pump.



7. Open the valve slowly.



8. When all air is out, close the vent.

9. Repeat the procedure for the other media.

5.2

5

Operation

UNIT IN OPERATION

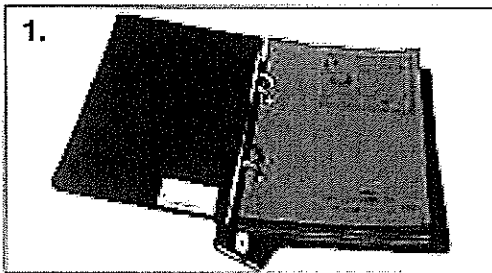
Any adjustment of the flowrates required to maintain correct temperatures or pressure drops should be made slowly, in order to prevent shocks to the system.

Problems in keeping up the performance of the heat exchanger may be caused by a change in some of the temperature conditions, the heat load or by fouling.

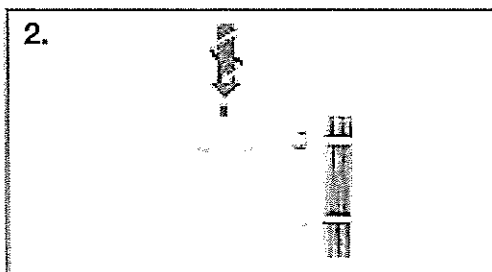
As long as the PHE is operating to satisfaction, it should be left without any interference.

SHUT-DOWN

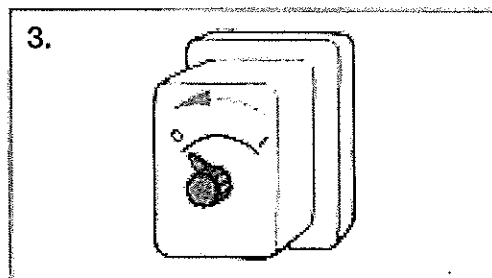
If the heat exchanger is going to be shut down - or if for any reason the pumps are to be stopped - the following procedure should be followed:



1. First establish whether instructions exist that specify which side should be stopped first.



2. SLOWLY CLOSE THE VALVE controlling the flow rate of the pump you are about to stop.
3. When the valve is closed, stop the pump.
4. Repeat the procedure for the other side.



5. Poor quality cooling water may be hazardous to metallic materials. Typical examples are corrosion of stainless steels and nickel alloys.

If for any reason the heat exchanger is shut down for a longer period (more than a number of days), it should be drained, and depending on the media processed, it is recommendable to rinse and dry it.

THE RISKS OF NOT COMPLYING WITH THE START-UP AND SHUT-DOWN PROCEDURES.

A liquid in motion in a pipe system represents a lot of energy, and it must be very carefully dealt with.

Particularly when the fluid is stopped it is imperative that this is done smoothly.

NOTE!

For this reason fast-closing valves should not be used unless the pipes of the system are very short.

Valves must be operated gradually. The longer the pipes and the higher the flow rate, the more important this becomes.

WATER HAMMER is the name given to a short duration pressure peak, traveling along the pipe as a wave at the speed of sound, and resulting from a sudden deceleration of the motion of the fluid in a closed system.

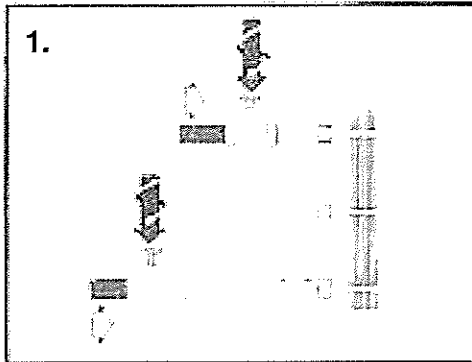
Thus, it is usually related to the shutting down of a system. However, when starting up a system with open valves and empty pipes, the fluid may burst into some obstacle, like a fine mesh strainer, a flow meter or a heat exchanger, causing a sudden reduction of the flow velocity - if not a complete halt, and so we may have the conditions of a Water Hammer.

In the worst case, the pressure surge caused by such a sudden stop of the motion of a fluid, can be several times the normal pressure of the system.

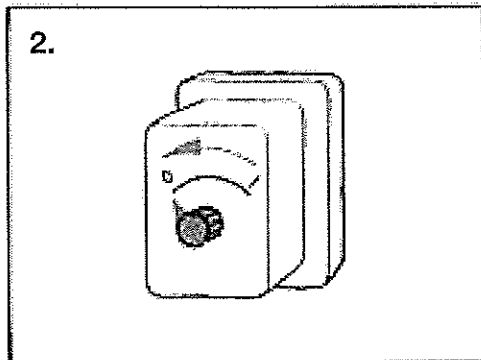
Therefore it is very important for the protection of the whole installation that start-ups and close-downs are carried out with great care.

6

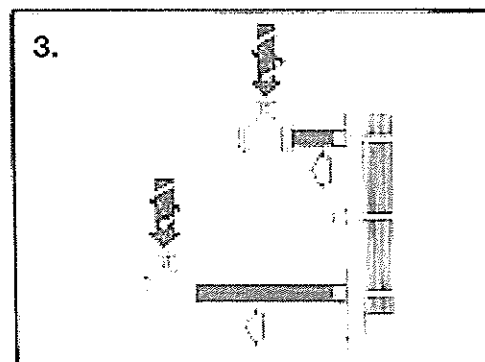
Opening



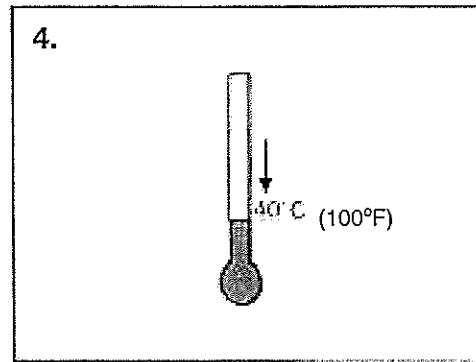
1. Slowly close the valves on the inlets. Shut off the inlet side, closing the highest pressure first.



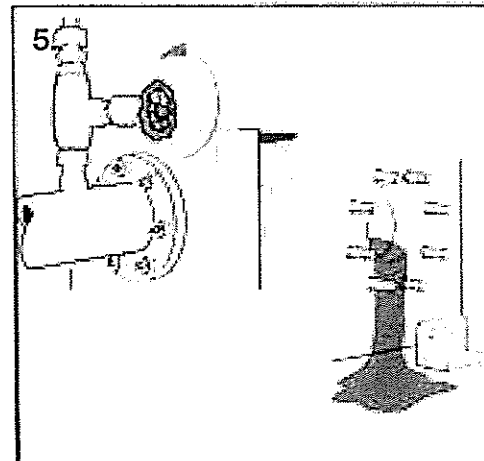
2. Switch off pumps.



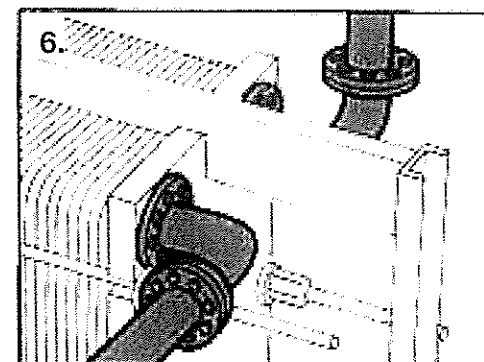
3. Close the valves on both outlets.



4. If the heat exchanger is hot, wait until it has cooled down to about 40°C (100°F).



5. Drain

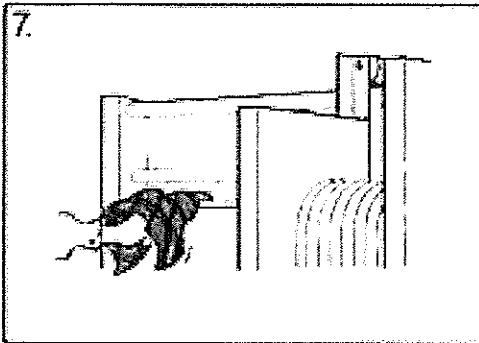


6. Dismantle any pipe bends connected to the pressure plate, so that it can be moved freely along the carrying bar.

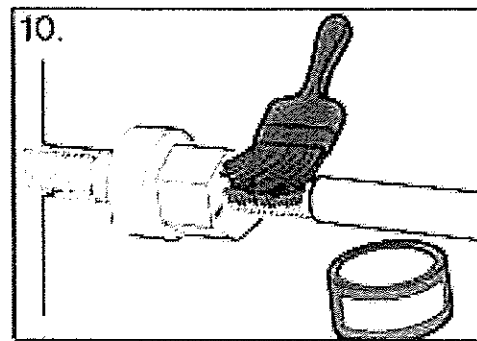
6.1

Opening

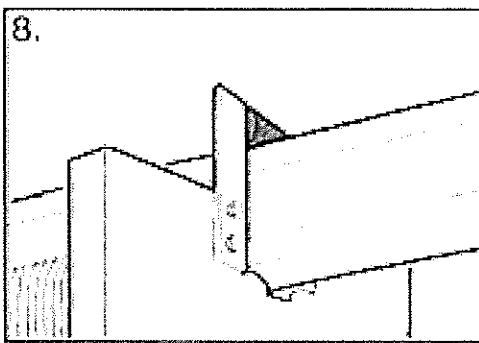
6



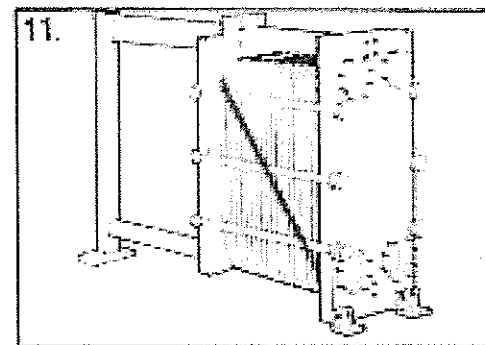
7. Inspect the sliding surfaces of the carrying bar and wipe clean



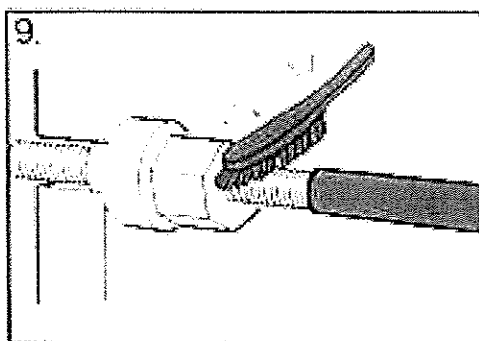
10. Lubricate the threads with a thin layer of grease, e.g LUBRIPLATE FGL-2 or equivalent.



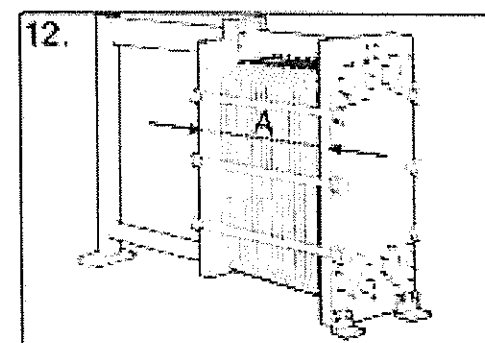
8. Inspect pressure plate roller.



11. Mark the plate assembly on the outside by a diagonal line, or number the plates in sequence.



9. Pull back the plastic covers on the tightening bolts; brush the threads clean with a steel wire brush.



12. Measure and note the dimension A. Compare with code plate and PHE documentation for this same serial number.

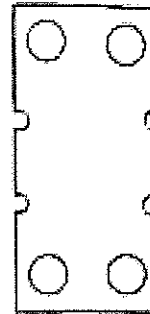
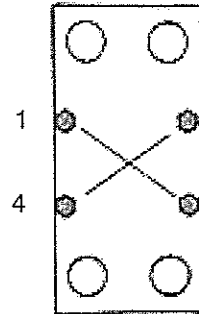
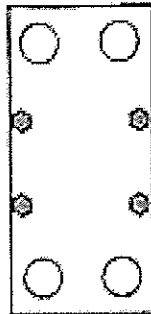
6.2

6

Opening

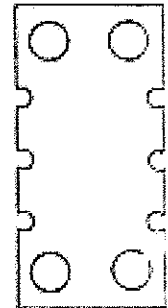
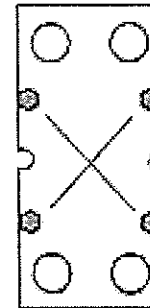
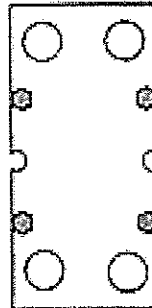
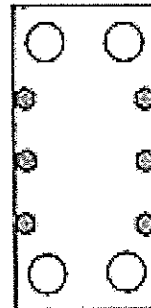
(13) (See page 6.5) (14)

	P2	A10B	TS6-M	AM10	M10B M10M
FG	X	X	X	X	
FM					X
FD			X		



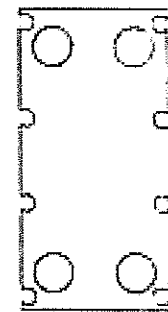
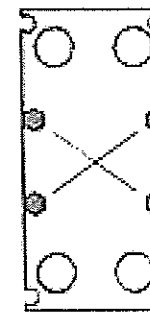
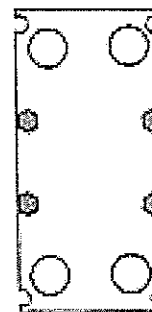
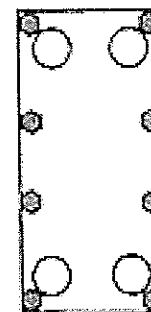
(13) (See page 6.5) (14)

	V8	P3	V13 V20	V28	M10B M10M	M10BW M10DW	M20-M
E		X					
FD			X				
FG			X	X	X	X	
FM							X
VG	X						



(13) (See page 6.5) (14)

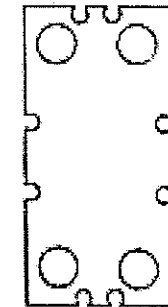
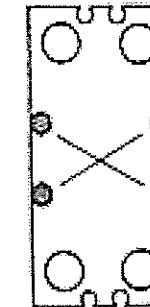
	M3	P2	P3	V28	V45
EH			X		
VG	X				
VLCH		X			
FG				X	X
FD				X	X



(13) (See page 6.5) (14)

	MX25B	A15BWA	15B	TS20-M	AM20 AM20B AM20W AM20S AM20DW	M6 M6M	M15M
FG		X	X	X	X	X	X
FD		X	X	X	X	X	X
FL			X				
FM	X			X			X
FS				X			

M6/M6-MFG & MX25-BFM ONLY HAS ONE BOLT TOP AND BOTTOM

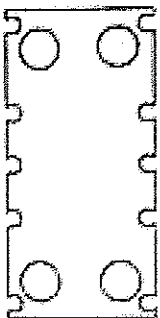
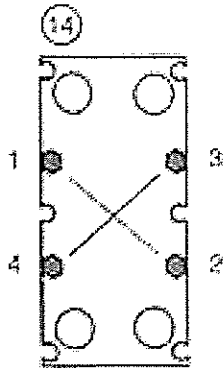
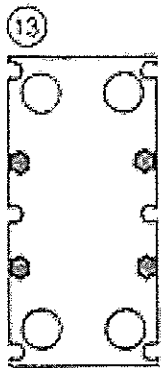
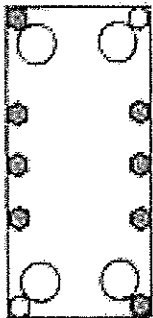


Opening

6

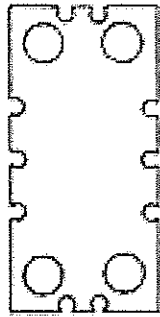
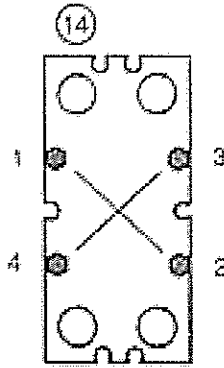
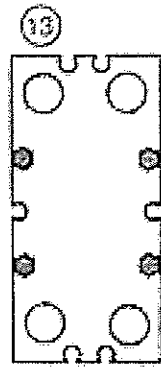
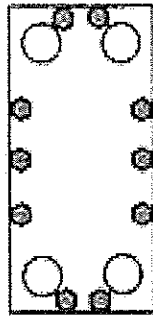
	M20-M			
FG				

M20-MFG ONLY HAS ONE BOLT
TOP AND BOTTOM

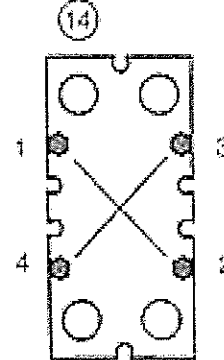
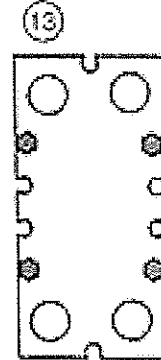
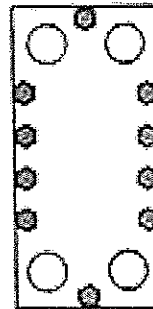


	M15B M15F	A20B	T200	M6 AK20 M6DW	M6M M30
FG		X	X		
FD				X	
FM					X
FS	X				

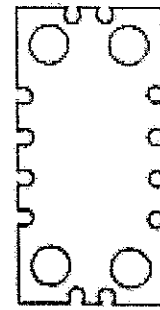
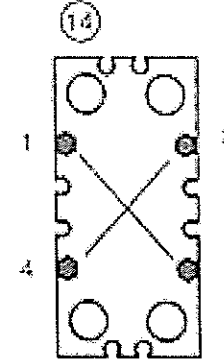
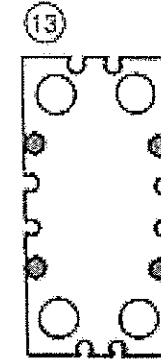
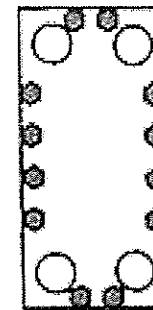
M6/M6-MFG ONLY HAS ONE BOLT
TOP AND BOTTOM



	M10B M10M	M10BW		
FD	X	X		



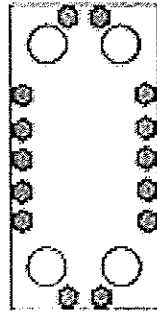
	A20B	AK20 T200	MX25B	V110
FD	X	X		
FL	X			
FG			X	X



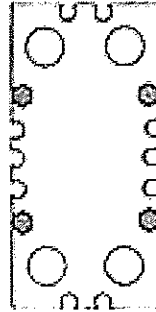
6

Opening

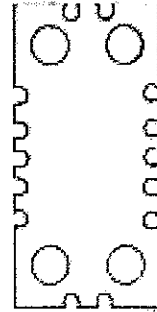
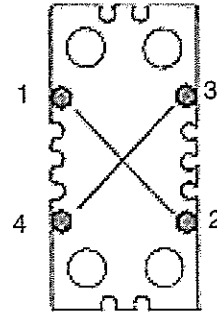
	AX30B AX30BW	V110		
FG FD	X	X		



13

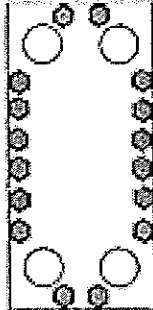


14

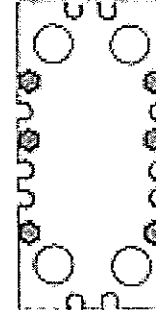


	AX30B AX30BW	A35 A45	AX35	M20M	M30	MX25B	V170 V280
FG FD HA FS	X 	 X 	X 	X 	X X 	X X 	X X

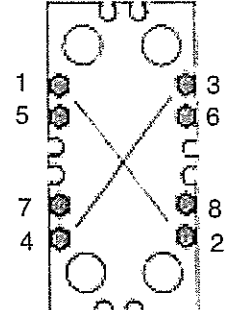
NOTE: M30-FD, MA30-FG/FD, MX25-BFS, V280-FG/FD and V170-FD have a twenty bolt or larger pattern, use this picture only as a guide. Start sequence numbers 5 and 6 at the fourth bolt down on both sides.



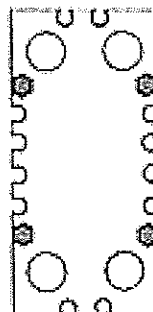
13



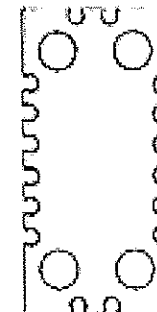
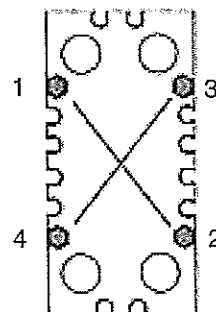
14



15



16



ORDER	BOLT NO.	TO DIM.
1	1-2-3-4-5-6	1.05A
2	1-2-3-4	1.10A
3	1-2 OR 3-4	OPENING

- 13 If bolts are fitted with bearing boxes loosen and remove them. If not fitted with bearing boxes, then follow the pictures above.
- 14 Loosen the remaining bolts, alternately and diagonally, to bring length to 1.05A.
- 15 Remove bolts 5 and 6 completely.

- 16 Continue opening, alternately and diagonally.

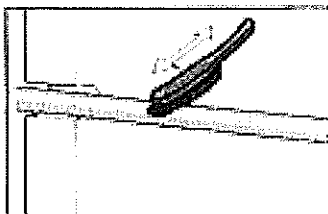
Note: Skewing of the Pressure Plate during opening must not exceed 10 mm (2 turns per bolts) across the width and 25 mm (5 turns per bolts) vertically.

6.5

Removal and insertion of plates

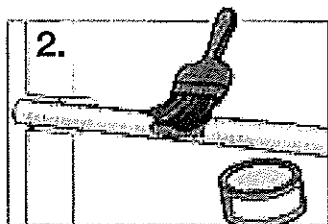
6

1.

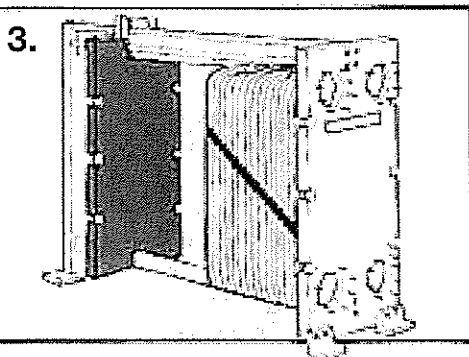


Brush the threads of the bolts clean, using a steel wire brush

2.

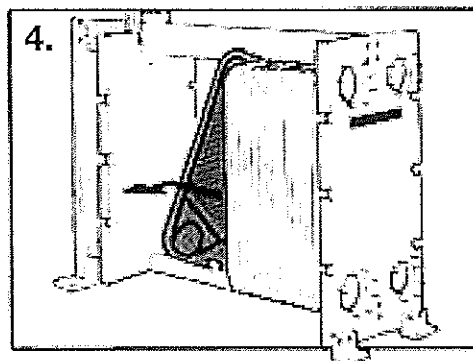


Lubricate the threads with a thin layer of grease, e.g. LUBRIPLATE FGL-2 or equivalent.



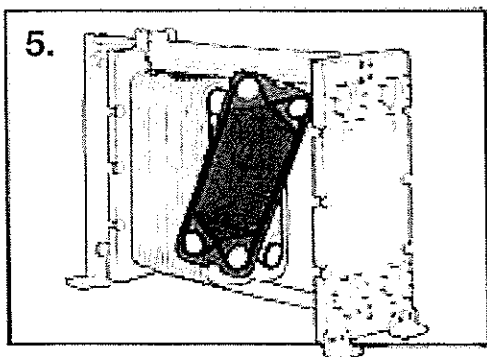
REMOVAL OF PLATES

3. Push the pressure plate against the support column.
4. Remove the plates. Stack them neatly on a skid or pallet for easy transporting.



INSERTION OF PLATES

5.

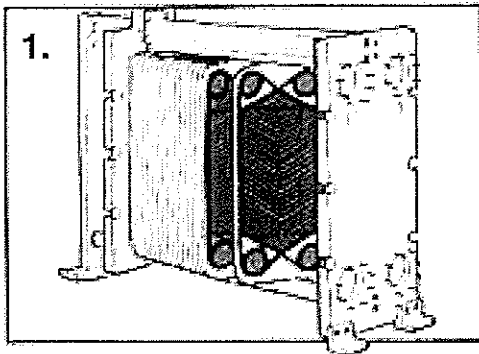


5. Hang the plates with their backs towards the pressure plate (the side without gasket).

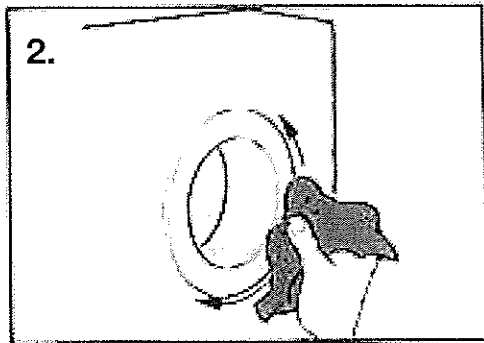
6.6

6

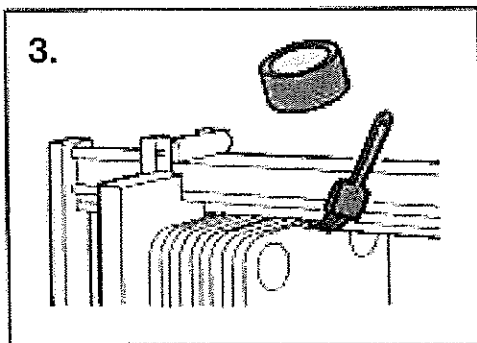
Closing



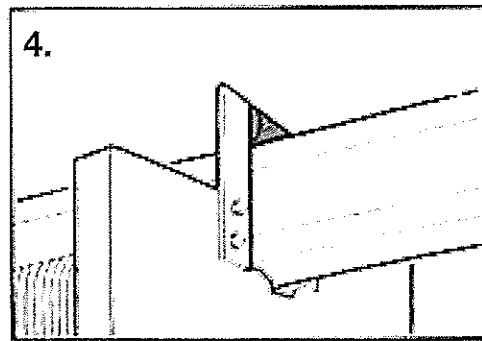
1. Check that all the sealing surfaces (i.e. surfaces in contact with the heat transfer medium) are clean.



2. Check that the ring gaskets or liners, when fitted in connections, are in position and are in good condition.

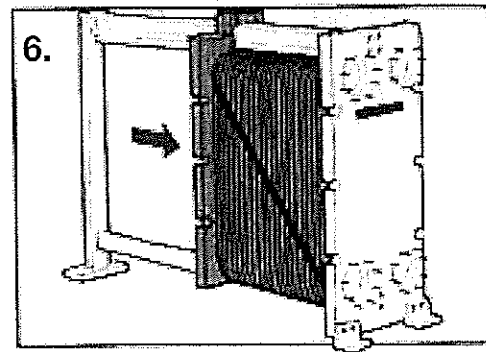


3. Clean and lubricate the sliding surfaces of the carrying bar.

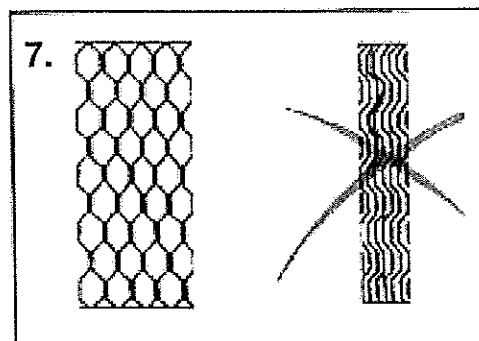


4. Inspect the pressure plate roller. Remove any debris from top surface of carrying bar.

5. Check against the drawing or flow sheet (provided with each heat exchanger) to make sure that the plates are hanging in the correct order.



6. Press the plate assembly together.



7. If the plates are correctly assembled, the edges form a "honeycomb" pattern.

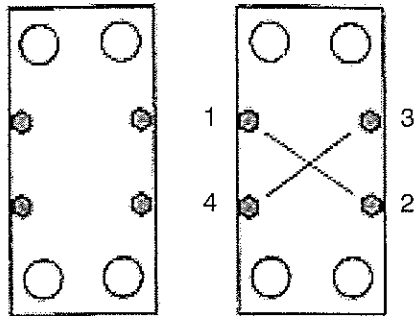
If the plate pack has been marked on the outside (fig. 6) check this.

Closing

6

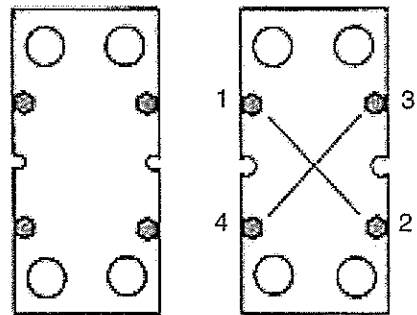
	P2	A10B	TS6-M	AM10	M10B M10M
FG	X	X	X	X	
FM					X
FD			X		

(8) (See page 6.11) (11)

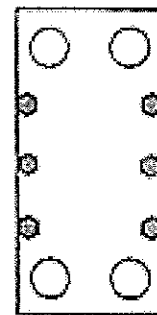


	V8	P3	V13 V20	V28	M10B M10M	M10BW M10DW	M20-M
E		X					
FD			X				
FG			X	X	X	X	
FM							X
VG	X						

(8) (See page 6.11) (11)

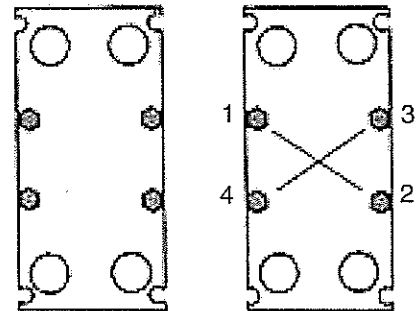


(14) (See page 6.11)

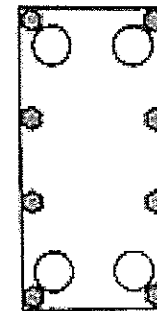


	M3	P2	P3	V28	V45
EH			X		
VG	X				
VLCH		X			
FG					X
FD				X	X

(8) (See page 6.11) (11)

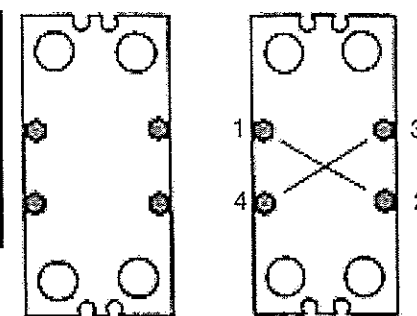


(14) (See page 6.11)

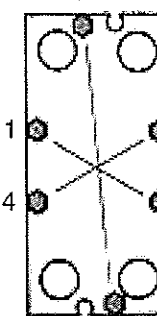


	MX25B	A15BW	A15B	TS20-M	AM20 AM20B AM20W AM20S	M6 M6M	M15M
FG		X	X	X	X	X	X
FD		X	X	X	X	X	X
FL			X				
FM	X			X			X
FS				X			

(8) (See page 6.11) (11)



(14) (See page 6.11)



M6/M6-MFG & MX25-BFM ONLY HAS ONE BOLT TOP AND BOTTOM

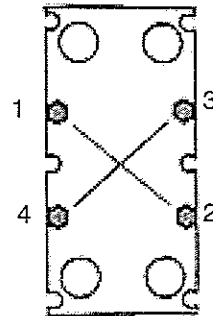
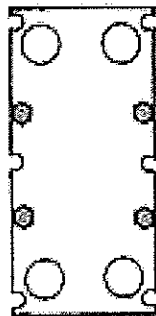
6

Closing

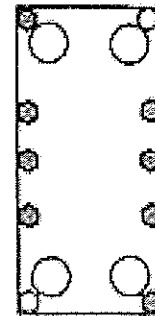
	M20-M			
FG				

M20-MFG ONLY HAS ONE BOLT TOP AND BOTTOM

(8) (See page 6.11) (11)



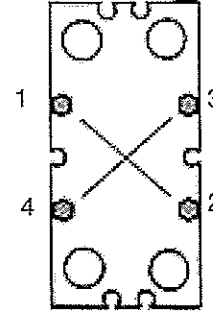
(14) (See page 6.11)



	M15B M15F	A20B	T200	M6 AK20 M6DW	M6M M30
FG		X	X		
FD				X	
FM					X
FS	X				

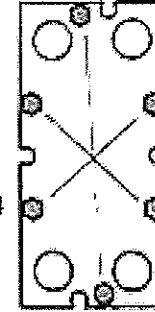
M6/M6-MFG ONLY HAS ONE BOLT TOP AND BOTTOM

(8) (See page 6.11) (11)

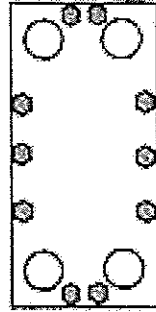


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(14) (See page 6.11)

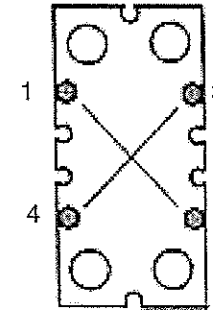
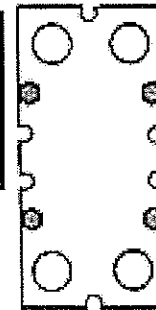


6



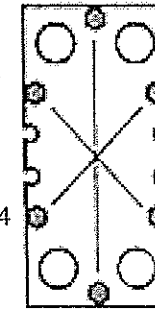
	M10B M10M	M10BW		
FD	X	X		

(8) (See page 6.11) (11)

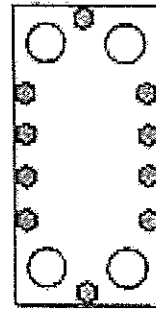


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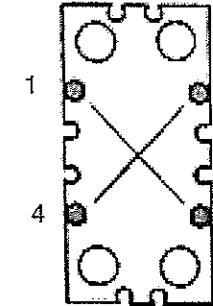
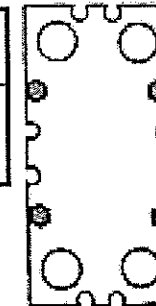
(14) (See page 6.11)



6

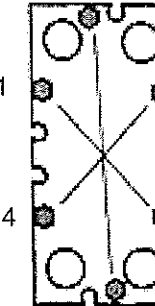


(8) (See page 6.11) (11)

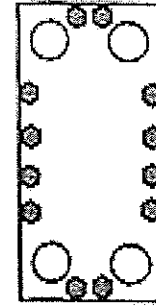


5

(14) (See page 6.11)



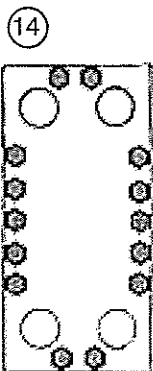
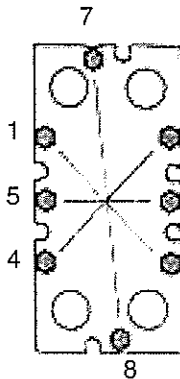
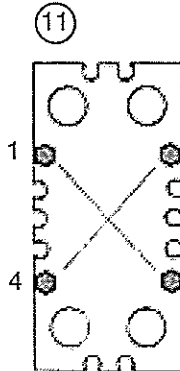
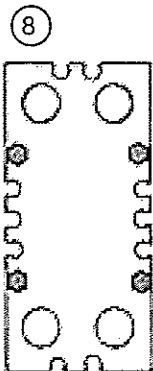
6



Closing

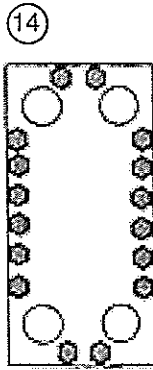
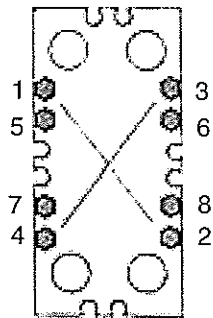
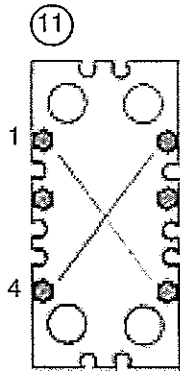
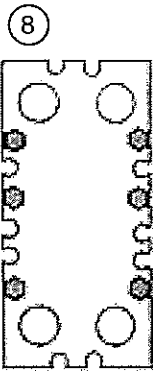
6

	AX30B AX30BW	V110		
FG FD	X	X		



	AX30B AX30BW	A35 A45	AX35	M20M	M30	MX25B	V170 V280
FG FD HA FS	X 	 X 	X 	X 	X X 	X X 	X X

NOTE: M30-FD, MA30-FG/FD, MX25-BFS, V280-FG/FD and V170-FD have a twenty bolt or larger pattern, use this picture only as a guide. Start sequence numbers 5 and 6 at the fourth bolt down on both sides.

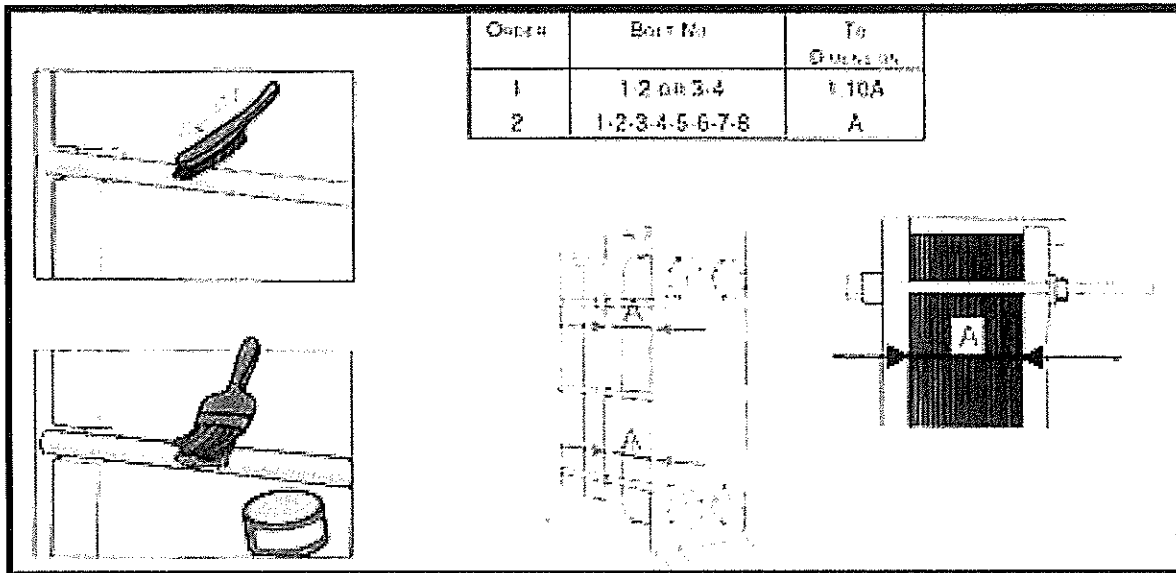


ORDER	BOLT NO.	TO DIM.
1	1-2-3-4-5-6	1.05A
2	1-2-3-4	1.10A
3	1-2 OR 3-4	OPENING

Note: See next page for closing instructions for all the models

6

Closing



8. Place all the bolts that are fitted with bearing boxes in position. If not fitted with bearing boxes then follow the pictures for your specific model.
9. Brush the threads of the bolts clean, using a steel wire brush.
10. Lubricate the threads with a thin layer of grease, e.g. LUBRIPLATE FGL-2 or equivalent.
11. Tightening is carried out alternately and diagonally, as shown on the figure above.
12. Check the dimension A during tightening at the positions of the bolts that are being used. Skewing of the pressure plate during tightening must not exceed 10mm (2 turns per bolt) across the width and 25 mm (5 turns per bolt) vertically.
13. Nominal plate pack length A can be exceeded in exceptional cases, the tightening can be stopped at the following dimensions

Plate pack length/plat	Plate pack length
> 4 mm	A + 1%
> 3mm, < 4mm	A + 1.5%

14. Place the other bolts in position.
 - Inspect the washers.
 - When fully tightened, the bolts should all be equally tensioned.
 - The difference between the plate pack lengths measured at adjacent bolts should not exceed:
 - 2mm when dimension A is < 1000mm
 - 4mm when dimension A is > 1000mm
 - The plate pack length at all bolts must not differ by more than 1%
 - If the unit does not seal fully, it can be tightened to the dimension A-1%.

IF DIMENSION A IS NOT REACHED WITH APPLICATION OF THE ABOVE STEPS:

- Check the number of plates and dimension A.
- Check that all the nuts and bearing boxes are running freely. If not, clean and lubricate or replace.
- Fit all the bolts, and tighten alternately.

6.11

Chlorine as growth inhibitor

Chlorine, commonly used as growth inhibitor in cooling water systems, reduces the corrosion resistance of stainless steels (including Hastelloy, Incoloy, Inconel and SMO).

Chlorine weakens the protection layer of these steels making them more susceptible to corrosion attacks than they otherwise should be. It is a matter of time of exposure and concentration.

In every case where chlorination of non-titanium equipment cannot be avoided, ALFA LAVAL must be consulted.

Contact the following address:

ALFA LAVAL

Heat Transfer Center

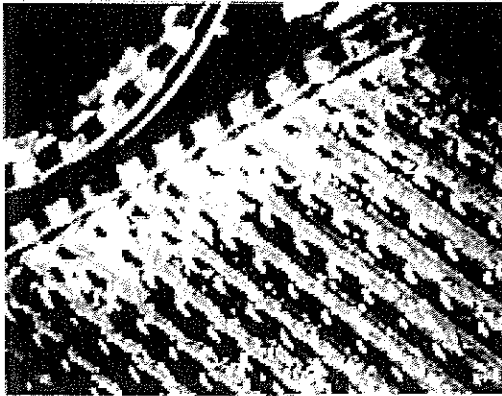
5400 International Trade Drive

Richmond, VA 23231

Phone (804) 222-5300

Fax (804) 236-3276

NOTE! Titanium is not affected by chlorine.

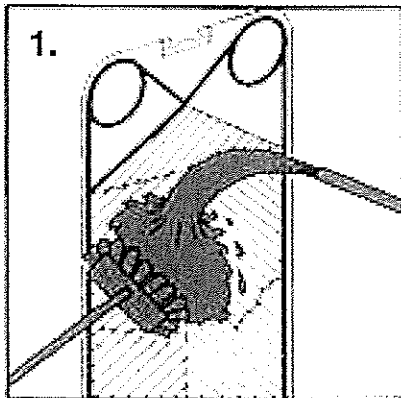


INCRUSTATION - SCALING

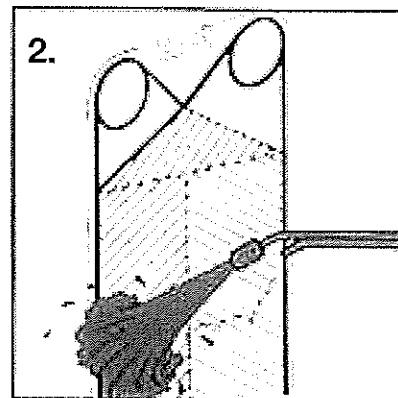
- Calcium carbonate
- Calcium sulphate
- Silicates

CLEANING

Mechanical cleaning after opening.



1. Soft brush and running water.
NOTE! Avoid gasket damage.



2. High pressure hose.

3. Chemical cleaning of opened unit by using:

- Nitric acid
- Sulfamic acid
- Citric Acid
- Phosphoric acid
- Complexing agents (EDTA, NTA)
- Sodium polyphosphates

Concentration max 4% by wt%
Temperature max 140° F

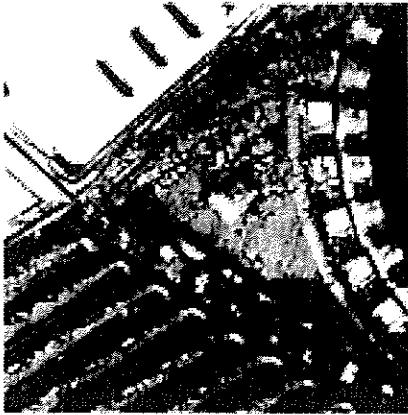
NOTE!

Under no circumstances should HYDROCHLORIC ACID be used with STAINLESS STEEL PLATES and under no circumstances should HYDROFLUORIC ACID be used with TITANIUM PLATES. Water of more than 300 ppm Chlorine may not be used for the preparation of cleaning solutions.

It is very important that carrying bars and support columns made of aluminum are protected against chemicals.

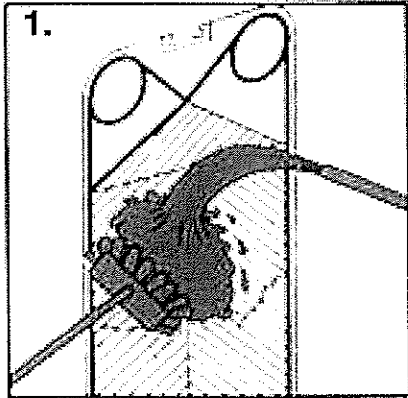
Cleaning

7



CLEANING

Mechanical cleaning after opening.

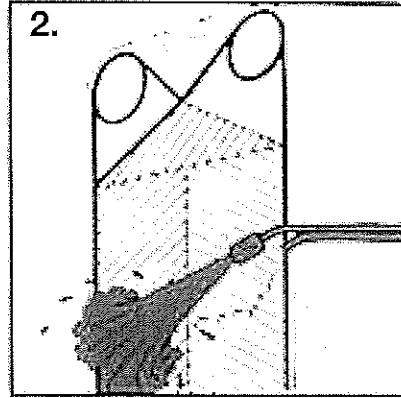


1. Soft brush and running water.
NOTE! Avoid gasket damage.
3. Chemical cleaning of opened unit by using:
 - Nitric acid
 - Sulfamic acid
 - Citric Acid
 - Phosphoric acid
 - Complexing agents (EDTA, NTA)
 - Sodium polyphosphates

Concentration max 4% by wt%
Temperature max 140° F

SEDIMENT

- Corrosion products
- Metal Oxides
- Silt
- Alumina
- Diatomic organisms and their excrement of various colors.



2. High pressure hose.
4. The addition of surfactants can improve cleaning effect.

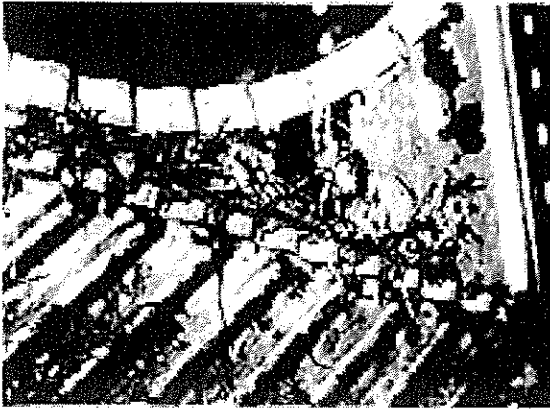
NOTE!

Under no circumstances should HYDROCHLORIC ACID be used with STAINLESS STEEL PLATES and under no circumstances should HYDROFLUORIC ACID be used with TITANIUM PLATES. Water of more than 300 ppm Chlorine may not be used for the preparation of cleaning solutions.

It is very important that carrying bars and support columns made of aluminum are protected against chemicals.

7

Cleaning



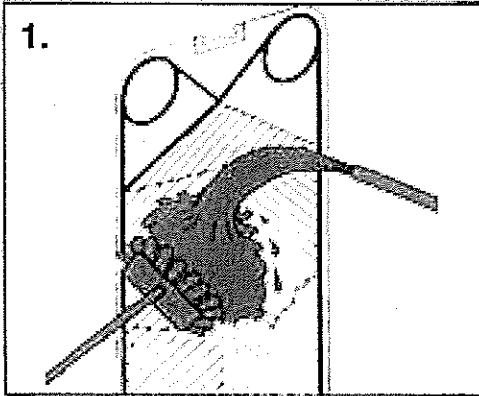
GROSS FOULING

- Seaweeds
- Wood chips/fibers
- Mussels
- Barnacles

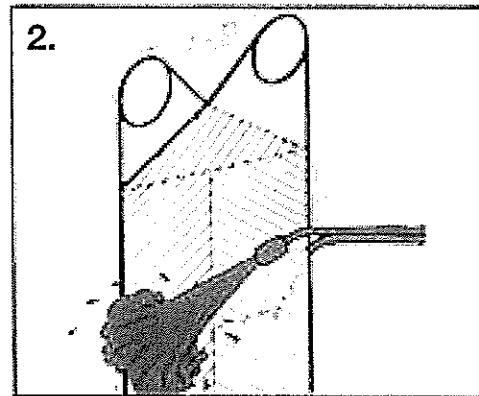
CLEANING:

NOTE: BACKFLUSHING OF THE UNOPENED HEAT EXCHANGER CAN SOMETIMES BE SUFFICIENTLY EFFECTIVE.

Mechanical cleaning after opening.



1. Soft brush and running water.
NOTE! Avoid gasket damage.



2. High pressure hose.

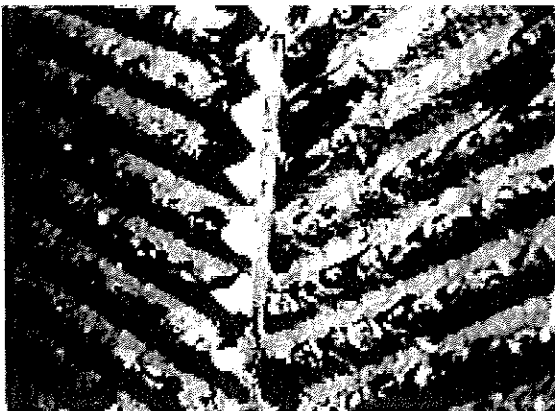
NOTE!

Under no circumstances should HYDROCHLORIC ACID be used with STAINLESS STEEL PLATES and under no circumstances should HYDROFLUORIC ACID be used with TITANIUM PLATES. Water of more than 300 ppm Chlorine may not be used for the preparation of cleaning solutions.

It is very important that carrying bars and support columns made of aluminum are protected against chemicals.

Cleaning

7

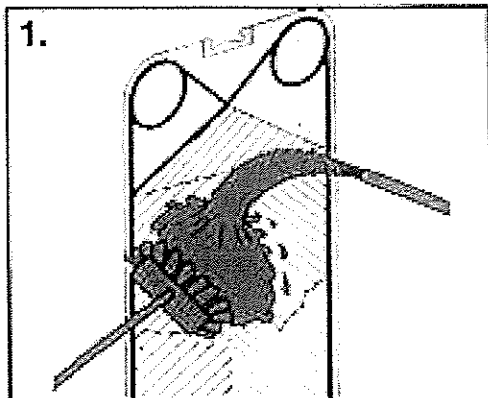


BIOLOGICAL GROWTH - SLIME

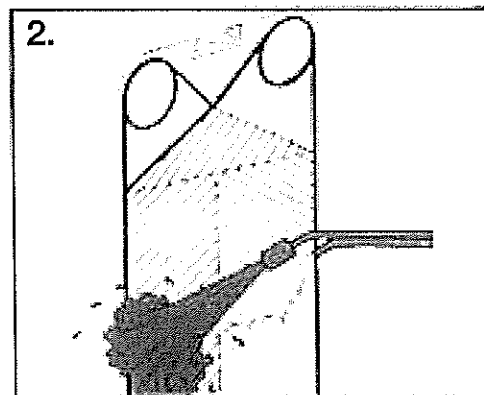
- Bacteria
- Nematodes
- Protozoa

CLEANING

Mechanical cleaning after opening.



1. Soft brush and running water.
NOTE! Avoid gasket damage.



2. High pressure hose.

3. Chemical cleaning of opened unit by using:

- Nitric acid
- Sulfamic acid
- Citric Acid
- Phosphoric acid
- Complexing agents (EDTA, NTA)
- Sodium polyphosphates

Concentration max 4% by wt%
Temperature max 140° F

NOTE!

Under no circumstances should HYDROCHLORIC ACID be used with STAINLESS STEEL PLATES and under no circumstances should HYDROFLUORIC ACID be used with TITANIUM PLATES. Water of more than 300 ppm Chlorine may not be used for the preparation of cleaning solutions.

It is very important that carrying bars and support columns made of aluminum are protected against chemicals.

7.4

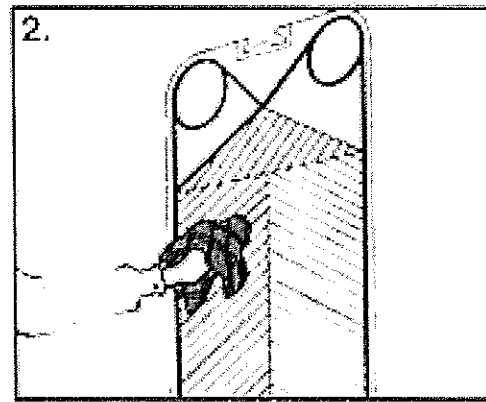
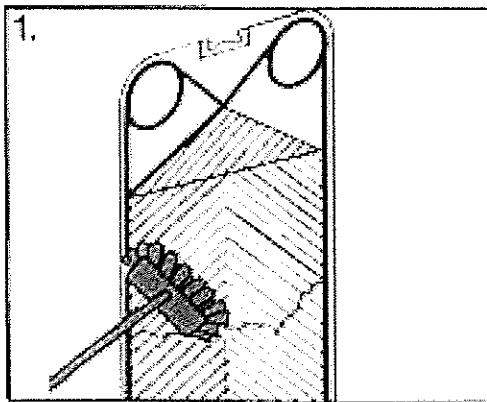
7

Cleaning

- Oil residues
- Asphalt
- Fats

CLEANING

Mechanical cleaning after opening.



1. Hydrocarbon-based deposits may be removed by using a soft brush and a PARAFFINIC or NAPHTHA-BASED solvent (e.g. KEROSENE).

2. Dry with a cloth or rinse with water.

NOTE!

Gaskets in natural, butyl and EPDM rubber swell in these media.

Contact time should be limited to 0.5 hour.

THE FOLLOWING SOLVENTS SHOULD NOT BE USED

- Ketones (e.g. Acetone, Methyl ethyl ketone, Methyl isobutyl ketone)
- Esters (e.g. Ethyl acetate, Butyl acetate)
- Halogenated hydrocarbons (e.g. Chloroethene, Carbon tetrachloride, Freons)
- Aromatics (e.g. Benzene, Toluene)

Regasketing

7

ALFA LAVAL has two types of glue for field repairs - GC11 and GC8 for repairs and exchange of gaskets in plates. A special glue is recommended for viton and silicone gaskets.

GC11

- A two-component, cold curing epoxy glue which gives a strong joint for higher temperatures.
- Future removal of gaskets usually requires heating or freezing of the joint.
- The shelf life is limited to approx. 1 year when stored at room temperature but can be prolonged when kept in a refrigerator.

GC8

- A single-component rubber-based solvent adhesive.
- Is normally used for repair work in an uncured condition.
- Can be used for operating temperatures below 200 F
- For operating temperatures above 200° F and oil coolers/heaters, the glued joints should be cured at 200° F for one hour.
- Future removal of the gasket can usually be carried out without heating of the cement joint.
- The storage life at room temperature is about two years. This period can be extended after checking the glue.

SEPARATE GLUING INSTRUCTIONS WILL BE
DELIVERED TOGETHER WITH THE GLUE.

ALFA LAVAL RECONDITIONING SERVICE

In addition to supplying genuine gaskets for your plate heat exchangers, we are able to provide a "SPECIALIZED PLATE RECONDITIONING SERVICE" to quickly and efficiently meet your service requirements.

Our reconditioning service includes a liquid nitrogen debonding process with chemical cleaning, crack detection and regasketing using a special epoxy/phenolic resin adhesive.

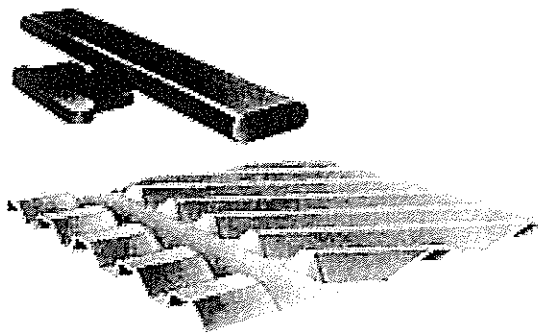
This regasketing process requires special oven curing of the cement to ensure the strongest

possible bond strength between plate and gasket, similar to the process used during manufacture. This is one reason why our service is guaranteed.

In most cases our reconditioning service has proved more economical and much faster when compared with on-site regasketing methods.

For further details, please contact your local ALFA LAVAL REPRESENTATIVE.
(See Section 1)

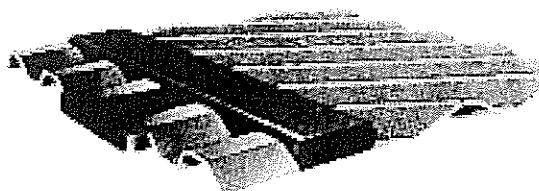
The Clip-on gasket - a glue-free gasket system



The Clip-on gasket is attached to the plate by two gasket prongs which slip under the edge of the plate to hold the gasket securely in alignment in the gasket groove.

The prongs are situated at regular intervals around the periphery of the plate.

When the plate heat exchanger is then assembled and tightened, the gasket provides a tight seal around the plate.



The Clip-on gasket in the gasket groove.

NOTE!

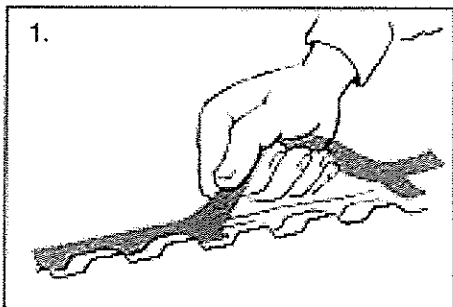
**Before closing of the equipment:
Check that the two gasket prongs
are in correct position.**

Regasketing of Snap-On Gaskets

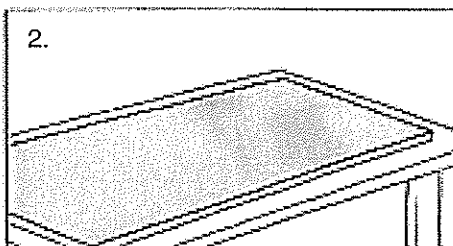
7

THE PROCEDURES (2-7) ARE NOT NECESSARY FOR DOING A SMALL QUANTITY OF PLATES.
THESE PROCEDURES WILL INCREASE SPEED OF REGASKETING OF LARGE QUANTITIES OF PLATES.

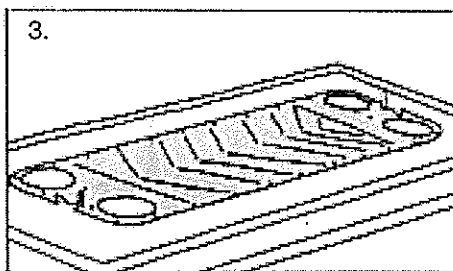
PREPARATORY PROCEDURES



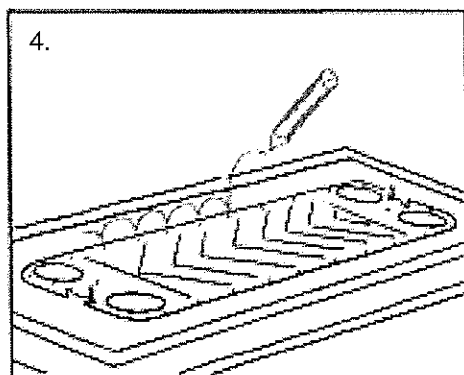
1. Pull the old gasket off the plate and clean the groove, if necessary.



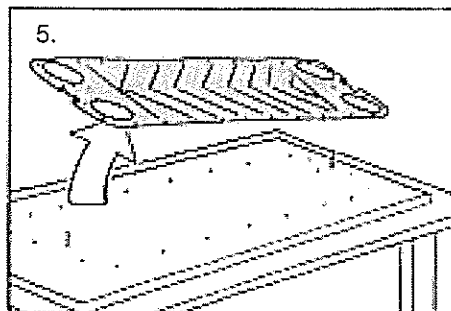
2. Place a flat sheet of plywood (somewhat larger than the PHE plate) on the table.



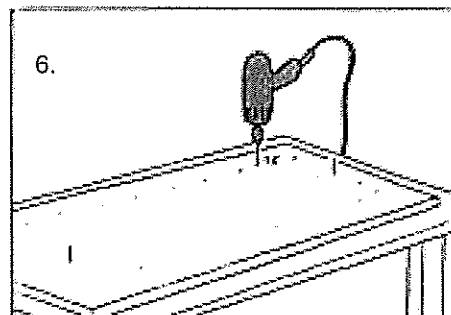
3. Place the PHE plate on the board with gasket groove upwards and fix firmly. Placing cylindrical pins in the plank at the carrying bar slots.



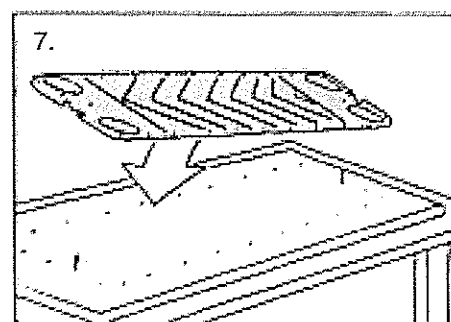
4. Make marks in the plank at all locations for gasket "snap-on".



5. Remove the plate.



6. Drill holes approx. 7mm dia and 10 mm deep in the plank at the marked spots. The plank is now a practical tool for regasketing of larger numbers of plates.

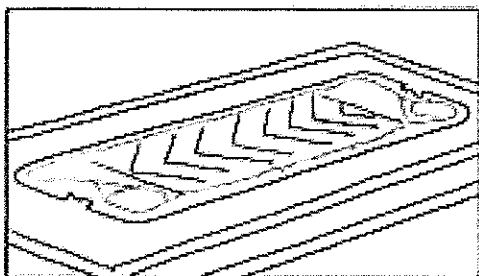


7. Replace PHE plate on the board in exactly the same location as at 3 above.

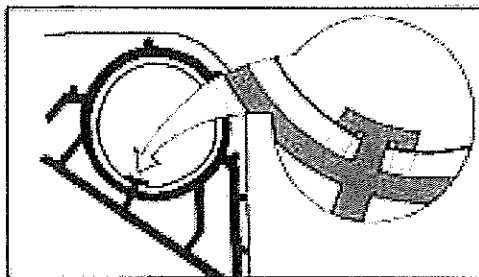
7.8

7 Regasketing of Snap-On Gaskets

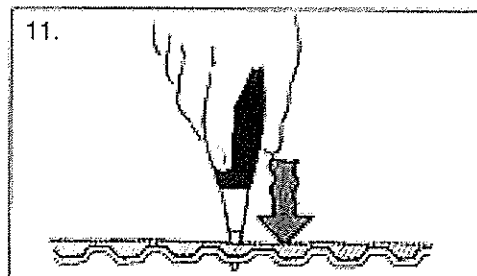
FASTENING OF THE "SNAP-ON" GASKET



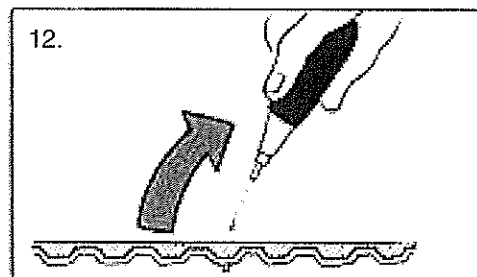
8. Place the gasket, with the "snap-on" projections downwards, in the gasket groove.



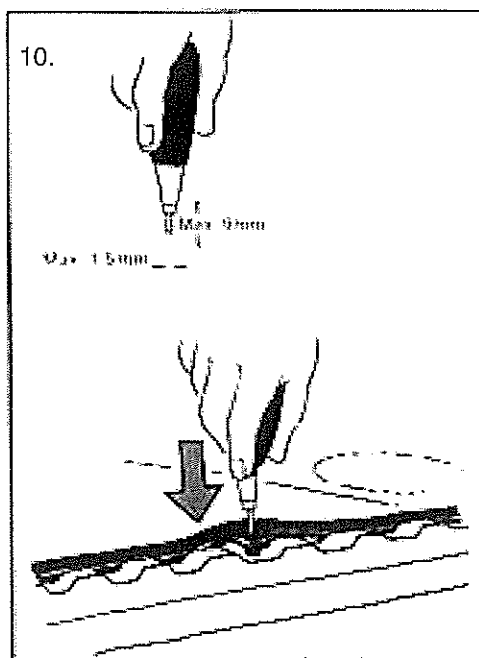
9. Place the ring gaskets in the groove and fix them with the T-flap.



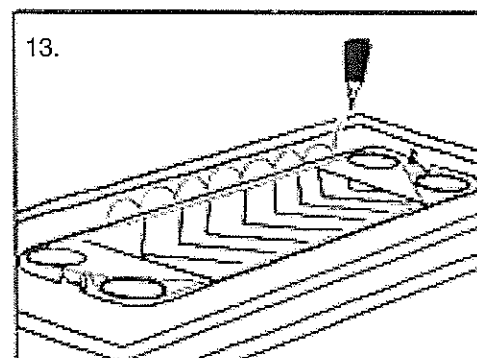
11. Push the projection through the hole in the plate.



12. Remove the tool point, and the projection is now "snapped on".



10. Insert the tool point into the recess in the projection.



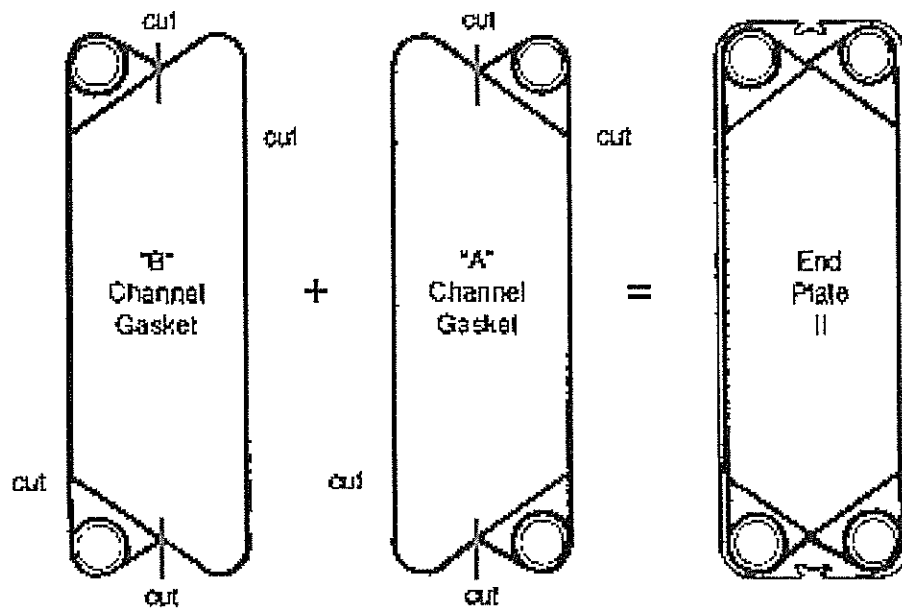
13. Repeat for all projections, and the gasket is "snapped on".

NOTE!
BEFORE CLOSING OF THE EQUIP-
MENT: CHECK THAT THE T-FLAPS
ARE IN CORRECT POSITION.

PARALLEL FLOW UNITS

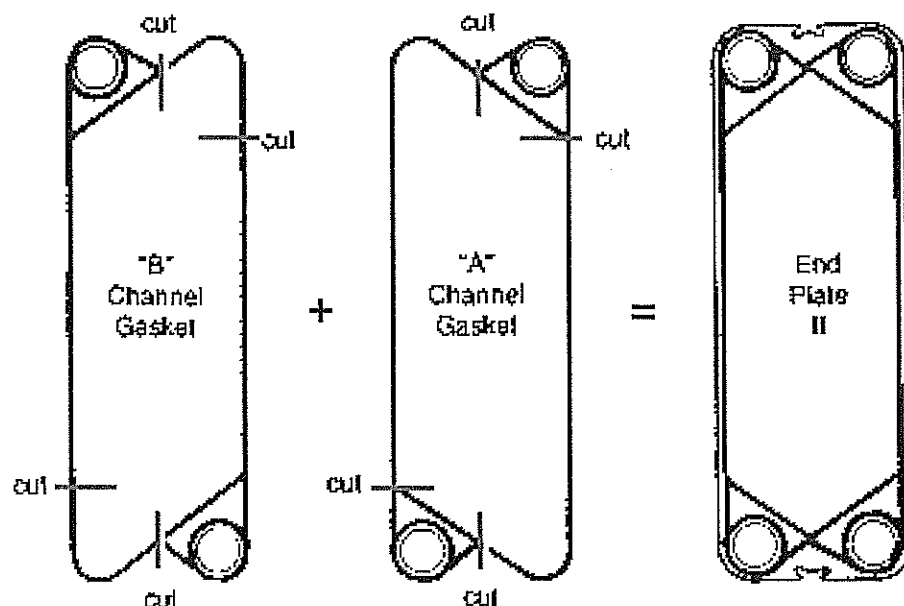
7

The End Plate II Gasket is formed by cutting (2) channel gaskets (as shown below) and gluing the gaskets to the first plate.



The (2) half channel gaskets should be glued to the end plate with GC-8 glue; or double sided tape (GC-1). The (4) port gasket areas are critical because these gaskets will be in contact with the process fluids.

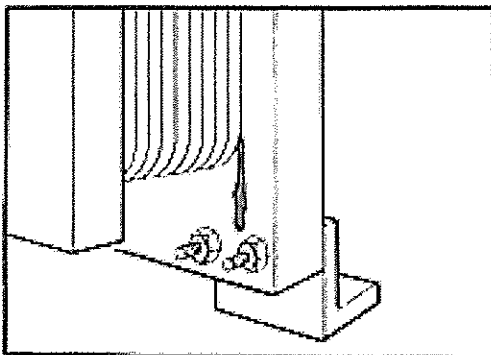
The End Plate II Gasket is formed by cutting (2) channel gaskets (as shown below) and gluing the gaskets to the first plate.



The (4) parts of the channel gaskets should be glued to the end plate with GC-8 glue; or double sided tape (GC-1). The (4) port gasket areas are critical because these gaskets will be in contact with the process fluids.

Fault detection

8



SYMPTOM

LEAKAGE between plates and frame.

ACTION

Mark with a felt tip or similar marker, mark the area where the leakage seems to be, and open the heat exchanger

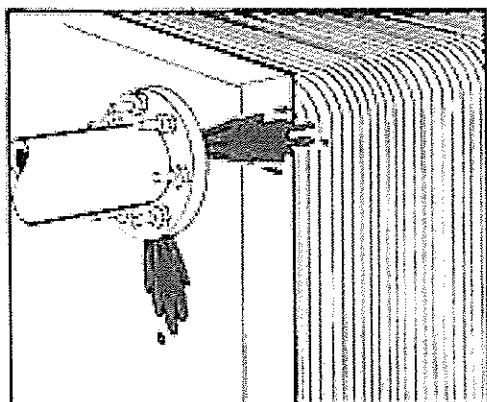
1. Investigate the gasket condition of the end plate and the connection if applicable, look for dislocation, foreign objects, scars and other damage to the gasket surfaces.
2. Check the surface of the pressure plate for unevenness, foreign objects sticking to it, etc. that might spoil the joint between the gasket and the adjacent surface.
3. Check the plate itself for cracks or holes.

CORRECTIONS

1. • Relocate gasket.
• remove foreign matter.
• replace connection lining if applicable.

Remove anything disturbing the joint between gasket and pressure plate surface.

A perforated end plate must be replaced.



SYMPTOM

LEAKAGE between flange and frame.

ACTION

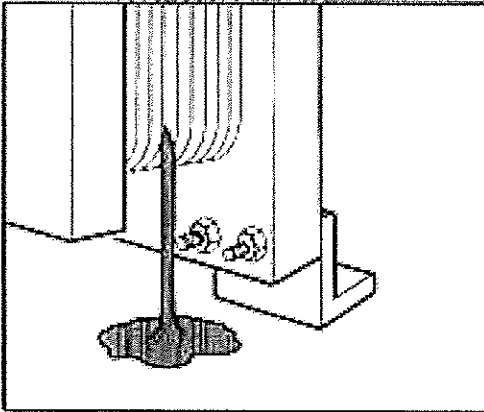
1. Disconnect the flange, and look for misalignment between flange and connection, dislocated or damaged gasket, foreign objects on the surface of the gasket or the flange.

CORRECTIONS

1. • Rearrange the pipe in order to eliminate stress and to correct alignment.
• relocate gasket
• replace damaged gasket
• replace connection lining if applicable
• remove foreign matter from flange and gasket
• reassemble, taking care to avoid misalignment

8.1

NOTE: On a Plate Heat Exchanger specially designed for high temperature duties, extreme and sudden temperature drops may sometimes cause a temporary leakage. A typical example is a sudden shutting-off of the hot medium flow. The heat exchanger will normally seal again, as soon as the temperatures of the equipment have stabilized.



SYMPTOM

LEAKAGE between plates to the outside.

ACTION

Mark the leakage area with a felt tip marker on the two plates next to the leakage, check and note the length of the plate pack between inside frame plate and inside pressure plate, and then open the heat exchanger.

1. Check for loose, dislocated or damaged gasket.
2. Check for plate damage in the area, and also check plate pack length against the drawing to see if possible plate or gasket damage could be caused by overtightening of the plate pack, or if the leakage itself may simply be caused by insufficient tightening.
3. Check hanger recess at both plate ends for deformations, which could cause misalignment between the plates.
4. Make sure that the plates are hanging correctly as A-B-A (see SECTION 4A or 4B).
5. Check for perforation of the plate (corrosion).

CORRECTIONS

1.
 - Relocate gasket.
 - Re-cement loose gasket, if applicable.
 - Replace damaged gasket.
2. A damaged plate must in most cases be taken out for repair or replacement. If it is a regular plate with 4 holes: take the damaged plate and the 4-hole plate just in front or just behind it out of the plate pack. The heat exchanger can now be reassembled and put back in service PROVIDED THE PLATE PACK IS TIGHTENED TO A NEW MEASUREMENT, WHICH IS EQUAL TO THE ONE ON THE DRAWING, REDUCED BY TWO TIMES THE SPACE REQUIRED PER PLATE. CONTACT ALFA LAVAL FOR ASSISTANCE IN THE RECALCULATION IF NECESSARY.
The small reduction of the heat transfer area is normally of no importance, at least not for a short period of time.
 - Insufficient tightening must be corrected - see the drawing.
3. Damaged hanger recesses must be repaired if possible, or the plate replaced. For temporary arrangement with reduced number of plates - see paragraph 2 above.
4. Incorrect sequence of plates must be corrected (A-B-A-B-..). MAKE SURE THAT NO PLATE HAS BEEN DAMAGED, BEFORE REASSEMBLING THE PLATE PACK!
5. Perforated plates must be replaced. For temporary solution, see paragraph 2.

SYMPTOM

LEAKAGE between plates.

ACTION

CORRECTIONS

1. Check that the piping is connected to the heat exchanger at correct locations.
 2. Open the lower connection on one side, raise pressure on the other side and by looking into the open connection try to detect any liquid from the pressurized side leaking in, and if so - approximately how far into the plate pack the leakage is located. If no leakage is detected, the reason for the mixing of media must be sought elsewhere. (see paragraph 5).
 3. If a leakage was detected, note the position of the leakage along the plate pack and then open the plate heat exchanger.
 4. Before starting on the plates themselves, check that the corner areas between the ring and the field gaskets are clear, that the leakage slots are open. This ensures that any leakage is out of the plate heat exchanger and is to atmosphere. Therefore no pressure can build up to force the media across the gasket sealing off the other liquid.
 5. If it has not been possible to locate the leakage as described in par. 2 above, it will be necessary to check each single plate for possible perforations, using any of the following methods:
 - put a strong light behind the plate and watch for light coming through fine holes or cracks.
 - use a magnifying glass to check suspect area.
 - use a chemical penetrant, after having cleaned the plates well.
1. Relocate piping to correct connections.
 4. All deposits or material which can block the free exit from the area must be removed. If the leak channels of the gasket have been destroyed, they must be reopened with a suitable tool, or the gasket replaced.
 5. Plates with holes must be replaced. The PHE may be temporarily operated with a reduced number of plates. See "LEAKAGE between plates to the outside".

SYMPTOM

PRESSURE DROP PROBLEMS,

Pressure drop has increased

ACTION

CORRECTIONS

Check that all valves are open including non return valves.

Measure the pressure just before and just after the heat exchanger, and the flow rate. For viscous media a membrane manometer with a diameter of at least 30 millimeters should be used. Measure or estimate the flow rate if possible. A bucket and a watch showing seconds may be sufficient for small flow rates. For larger flow rates, some type of flowmeter is required. Compare the pressure drop observed with the one specified for the actual flow rate. (see plate print out)

1. If the pressure drop is higher than specified, the temperature program should also be checked:

1.1 If the thermometer readings correspond to those specified, the heat transfer surface is probably clean enough, but the inlet to the heat exchanger may be clogged by some objects.

1.2 If the thermometer readings are NOT corresponding to those specified, heat transfer is obviously dropping below specifications, because of deposits on the heat transfer surface, which at the same time also increase the pressure drop, since the passage becomes narrower.

2. If the pressure drop corresponds to the specifications, there is no need for any action.

3. If the pressure drop is lower than specified, the pump capacity is too small or the observation is wrong.

1. See next paragraph.

1.1 Open the PHE and take out whatever is clogging the passage, or use the back-flush system - if there is one - to rinse out the cloggings.

1.2 If a "cleaning-in-place" system is available, follow the instruction and use it to wash out the deposits. If not, open the PHE and clean the plates.

2. See pump instruction manual.

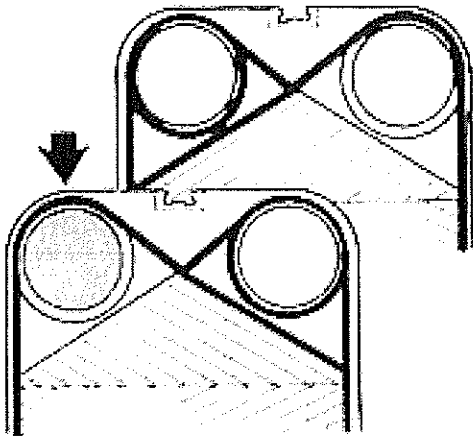
SYMPTOM: HEAT TRANSFER PROBLEMS

The heat transfer capacity is dropping

ACTION	CORRECTIONS
Measure temperatures at inlet and outlets and also flow rates on both media, if possible. At least on one of the media, both temperatures and the flow rate must be measured. Check to see if the transferred amount of heat energy corresponds to the specifications. If great precision is important, it will be necessary to use laboratory thermometers with an accuracy of 0.2 degrees Fahrenheit, and also to use the best equipment available for flow measurements.	If the heat transfer capacity of the equipment has dropped below specified values, the heat transfer surface must be cleaned. Either use the "cleaning-in-place" arrangement if provided or open the heat exchanger for visual inspection and manual cleaning. NOTE: Contact the Alfa Laval Sales & Service Division for CIP recommendations (See Section 1).

9

Supplementary Parts



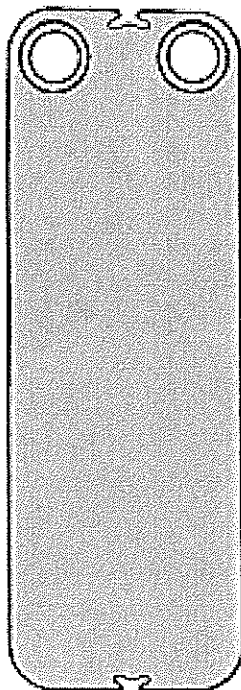
THE PARTITION PLATE - for special cases only.

If for instance, the thermal program requires that at least one of the media is to flow in more than one group through the plate package, there will be heat transfer plates with fewer than 4 holes.

To prevent the thin metal collapsing under the differential pressure, un-punched corners require extra support.

The extra support is provided by a partition plate - approximately the size of a channel plate - made of about 1/4" - 3/4" thick plate material with lined holes where a free passage is required.

The partition plate is suspended from the carrying bar. Where partition plates are required, in units with 8" ports or larger, there will be one at every turning point in a multi-grouped plate package.



Example only

9.1

ALFA
LAVAL

HAWTHORNE PACIFIC CORP. - OAHU

94-025 Farrington Hwy.

Waipahu, HI 96797

Fax: 676-0264

Department	Phone	Hours of Operation	
Sales	676-0205	07:30 - 04:00 p.m.	Monday - Friday
Parts	676-0200	07:00 - 04:00 p.m.	Monday - Friday
Service	676-0312 or -0313	07:00 - 03:30 p.m.	Monday - Friday

After Hours, Weekends, and Holidays		
Parts	676-0235	
Service	864-4916	676-0313

Dave Andrews

Effective with sales to the first user on or after June 1, 2012

CATERPILLAR LIMITED WARRANTY

Industrial, Petroleum, Locomotive, and Agriculture Engine Products and Electric Power Generation Products Worldwide

Caterpillar Inc. or any of its subsidiaries ("Caterpillar") warrants new and remanufactured engines and electric power generation products sold by it (including any products of other manufacturers packaged and sold by Caterpillar), to be free from defects in material and workmanship.

This warranty does not apply to engines sold for use in on-highway vehicle or marine applications; engines in machines manufactured by or for Caterpillar; C175, 3500 and 3600 series engines used in locomotive applications; 3000 Family engines, C0.5 through C4.4 and ACERT (C6.6, C7, C7.1, C9, C9.3, C11, C13, C15, C18, C27, and C32) engines used in industrial, mobile agriculture and locomotive applications; or Cat Batteries. These products are covered by other Caterpillar warranties.

This warranty is subject to the following:

Warranty Period

- For new industrial engines, engines in a petroleum applications or Petroleum Power Systems (excluding petroleum fire pump application), or engines in a Locomotive application, or Uninterruptible Power Supply (UPS) systems, the warranty period is 12 months after date of delivery to the first user.
- For new engines used in petroleum fire pump and mobile agriculture applications the warranty period is 24 months after date of delivery to the first user.
- For controls only (EPC), configurable and custom switchgear products, and automatic transfer switch products, the warranty period is 24 months after date of delivery to the first user.
- For CG132, CG170 and CG260 series power generation products the warranty period is 24 months/16,000 hours, whichever comes first, after date of delivery to first user.
- For electric power generation products other than CG132, CG170 and CG260 series in prime or continuous applications the warranty period is 12 months. For standby applications the warranty period is 24 months/1000 hours. For emergency standby applications the warranty period is 24 months/400 hours. All terms begin after date of delivery to the first user.
- For all Remanufactured Generator (GenEnds) products in prime or continuous applications the warranty period is

12 months. For standby applications the warranty period is 24 months/1000 hours. For emergency standby applications the warranty period is 24 months/400 hours. All terms begin after date of delivery to the first user.

- For all Remanufactured engines, the warranty period is 6 months (12 months for mobile agricultural and standby electric power generation applications) after date of delivery to the first user.
- For all other applications the warranty period is 12 months after date of delivery to the first user.

Caterpillar Responsibilities

If a defect in material or workmanship is found during the warranty period, Caterpillar will, during normal working hours and at a place of business of a Cat dealer or other source approved by Caterpillar:

- Provide (at Caterpillar's choice) new, Remanufactured, or Caterpillar approved repaired parts or assembled components needed to correct the defect.

Note: New, remanufactured, or Caterpillar approved repaired parts or assembled components provided under the terms of this warranty are warranted for the remainder of the warranty period applicable to the product in which installed as if such parts were original components of that product. Items replaced under this warranty become the property of Caterpillar.

- Replace lubricating oil, filters, coolant, and other service items made unusable by the defect.
- Provide reasonable and customary labor needed to correct the defect, including labor to disconnect the product from and reconnect the product to its attached equipment, mounting, and support systems, if required.
- For new 3114, 3116, and 3126 engines and electric power generation products (including any new products of other manufacturers packaged and sold by Caterpillar):
 - Provide travel labor, up to four hours round trip, if in the opinion of Caterpillar, the product cannot reasonably be transported to a place of business of a Cat dealer or other source approved by Caterpillar (travel labor in excess of four hours round trip, and any meals, mileage, lodging, etc. is the user's responsibility).

For all other products:

- Provide reasonable travel expenses for authorized mechanics, including meals, mileage, and lodging, when Caterpillar chooses to make the repair on-site.

User Responsibilities

The user is responsible for:

- Providing proof of the delivery date to the first user.
- Labor costs, except as stated under "Caterpillar Responsibilities," including costs beyond those required to disconnect the product from and reconnect the product to its attached equipment, mounting, and support systems.
- Travel or transporting costs, except as stated under "Caterpillar Responsibilities."
- Premium or overtime labor costs.
- Parts shipping charges in excess of those that are usual and customary.
- Local taxes, if applicable.
- Costs to investigate complaints, unless the problem is caused by a defect in Caterpillar material or workmanship.
- Giving timely notice of a warrantable failure and promptly making the product available for repair.
- Performance of the required maintenance (including use of proper fuel, oil, lubricants, and coolant) and items replaced due to normal wear and tear.
- Allowing Caterpillar access to all electronically stored data.

Limitations

Caterpillar is not responsible for:

- Failures resulting from any use or installation that Caterpillar judges improper.
- Failures resulting from attachments, accessory items, and parts not sold or approved by Caterpillar.
- Failures resulting from abuse, neglect, and/or improper repair.

(continue on the reverse side.....)

- Failures resulting from user's delay in making the product available after being notified of a potential product problem.
- Failures resulting from unauthorized repairs or adjustments, and unauthorized fuel setting changes.

- Damage to parts, fixtures, accessories items that are not part of the engine or electric power generation product (including any products of other manufacturers packaged and sold by Caterpillar).

- Repair of components sold by Caterpillar that is warranted directly to the user by their respective manufacturer. Depending on type of application, certain exclusions may apply. Consult your Cat dealer for more information.

For products operating outside of Australia, Fiji, Nauru, New Caledonia, New Zealand, Papua New Guinea, the Solomon Islands and Tahiti, the following is applicable:

NEITHER THE FOREGOING EXPRESS WARRANTY NOR ANY OTHER WARRANTY BY CATERPILLAR, EXPRESS OR IMPLIED, IS APPLICABLE TO ANY ITEM CATERPILLAR SELLS THAT IS WARRANTED DIRECTLY TO THE USER BY ITS MANUFACTURER.

THIS WARRANTY IS EXPRESSLY IN LIEU OF ANY OTHER WARRANTIES, EXPRESS OR IMPLIED, INCLUDING ANY WARRANTY OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE, EXCEPT CATERPILLAR EMISSION-RELATED COMPONENTS WARRANTIES FOR NEW ENGINES, WHERE APPLICABLE. REMEDIES UNDER THIS WARRANTY ARE LIMITED TO THE PROVISION OF MATERIAL AND SERVICES, AS SPECIFIED HEREIN.

CATERPILLAR IS NOT RESPONSIBLE FOR INCIDENTAL OR CONSEQUENTIAL DAMAGES.

CATERPILLAR EXCLUDES ALL LIABILITY FOR OR ARISING FROM ANY NEGLIGENCE ON ITS PART OR ON THE PART OF ANY OF ITS EMPLOYEES, AGENTS OR REPRESENTATIVES IN RESPECT OF THE MANUFACTURE OR SUPPLY OF GOODS OR THE PROVISION OF SERVICES RELATING TO THE GOODS.

IF OTHERWISE APPLICABLE, THE VIENNA CONVENTION ON CONTRACTS FOR THE INTERNATIONAL SALE OF GOODS IS EXCLUDED IN ITS ENTIRETY.

For personal or family use engines or electric power generation products, operating in the USA, its territories and possessions, some states do not allow limitations on how long an implied warranty may last nor allow the exclusion or limitation of incidental or consequential damages. Therefore, the previously expressed exclusion may not apply to you. This warranty gives you specific legal rights and you may also have other rights, which vary by jurisdiction. To find the location of the nearest Cat dealer or other authorized repair facility, call (800) 447-4986. If you have questions concerning this warranty or its applications, call or write:

In USA and Canada: Caterpillar Inc., Engine Division, P. O. Box 610, Mossville, IL 61552-0610, Attention: Customer Service Manager, Telephone (800) 447-4986. Outside the USA and Canada: Contact your Cat dealer.

For products operating in Australia, Fiji, Nauru, New Caledonia, New Zealand, Papua New Guinea, the Solomon Islands and Tahiti, the following is applicable:

THIS WARRANTY IS IN ADDITION TO WARRANTIES AND CONDITIONS IMPLIED BY STATUTE AND OTHER STATUTORY RIGHTS AND OBLIGATIONS THAT BY ANY APPLICABLE LAW CANNOT BE EXCLUDED, RESTRICTED OR MODIFIED ("MANDATORY RIGHTS"). ALL OTHER WARRANTIES OR CONDITIONS, EXPRESS OR IMPLIED (BY STATUTE OR OTHERWISE), ARE EXCLUDED.

NEITHER THIS WARRANTY NOR ANY OTHER CONDITION OR WARRANTY BY CATERPILLAR, EXPRESS OR IMPLIED (SUBJECT ONLY TO THE MANDATORY RIGHTS), IS APPLICABLE TO ANY ITEM CATERPILLAR SELLS THAT IS WARRANTED DIRECTLY TO THE USER BY ITS MANUFACTURER.

TO THE EXTENT PERMITTED UNDER THE MANDATORY RIGHTS, IF CATERPILLAR IS THE SUPPLIER TO THE USER, CATERPILLAR'S LIABILITY SHALL BE LIMITED AT ITS OPTION TO (a) IN THE CASE OF SERVICES, THE SUPPLY OF THE SERVICES AGAIN OR THE PAYMENT OF THE COST OF HAVING THE SERVICES SUPPLIED AGAIN, AND (b) IN THE CASE OF GOODS, THE REPAIR OR REPLACEMENT OF THE GOODS, THE SUPPLY OF EQUIVALENT GOODS, THE PAYMENT OF THE COST OF SUCH REPAIR OR REPLACEMENT OR THE ACQUISITION OF EQUIVALENT GOODS.

CATERPILLAR EXCLUDES ALL LIABILITY FOR OR ARISING FROM ANY NEGLIGENCE ON ITS PART OR ON THE PART OF ANY OF ITS EMPLOYEES, AGENTS OR REPRESENTATIVES IN RESPECT OF THE MANUFACTURE OR SUPPLY OF GOODS OR THE PROVISION OF SERVICES RELATING TO THE GOODS.

CATERPILLAR IS NOT LIABLE FOR INCIDENTAL OR CONSEQUENTIAL DAMAGES UNLESS IMPOSED UNDER MANDATORY RIGHTS.

IF OTHERWISE APPLICABLE, THE VIENNA CONVENTION ON CONTRACTS FOR THE INTERNATIONAL SALE OF GOODS IS EXCLUDED IN ITS ENTIRETY.

This warranty covers every major component of the products. Claims under this warranty should be submitted to a place of business of a Cat dealer or other source approved by Caterpillar. For further information concerning either the location to submit claims or Caterpillar as the issuer of this warranty, write Caterpillar Inc., 100 N. E. Adams St., Peoria, IL USA 61629.

CALIFORNIA EMISSION CONTROL WARRANTY STATEMENT YOUR WARRANTY RIGHTS AND OBLIGATIONS

The California Air Resources Board and Caterpillar Inc. ("Caterpillar") are pleased to explain the emission control system warranty on your 2011 and later engine. In California, new off-road engines must be designed, built, and equipped to meet the State's stringent anti-smog standards. Caterpillar must warrant the emission control system on your engine for the periods of time listed below provided there has been no abuse, neglect or improper maintenance of your engine. Caterpillar must warrant the emission control system on your engine for the periods of time listed below provided there has been no abuse, neglect or improper maintenance of your engine.

Your emission control system may include parts such as fuel-injection system and the air induction system. Also included may be hoses, belts, connectors and other emission-related assemblies.

Where a warrantable condition exists, Caterpillar will repair your heavy-duty off-road engine at no cost to you including diagnosis, parts, and labor.

MANUFACTURER'S WARRANTY COVERAGE:

The 2011 and later heavy-duty off-road engines are warranted for the warranty period set forth below. If any emission-related part on your engine is defective, the part will be repaired or replaced by Caterpillar.

OWNER'S WARRANTY RESPONSIBILITIES:

- As the off-road engine owner, you are responsible for the performance of the required maintenance listed in your owner's manual. Caterpillar recommends that you retain all receipts covering maintenance on your off-road engine, but Caterpillar cannot deny warranty solely for the lack of receipts or for your failure to ensure the performance of all scheduled maintenance.
- As the off-road engine owner, you should however be aware that Caterpillar may deny you warranty coverage if your off-road engine or a part has failed due to abuse, neglect, improper maintenance or unapproved modifications.
- Your engine is designed to operate on diesel fuel only. Use of any other fuel may result in your engine no longer operating in compliance with California's emissions requirements.
- You are responsible for initiating the warranty process. The ARB suggests that you present your off-road engine to a Caterpillar dealer as soon as a problem exists. The warranty repairs should be completed by the dealer as expeditiously as possible.

If you have any questions regarding your warranty rights and responsibilities, you should contact Caterpillar Inc., Warranty Manager at 1-309-675-1000.

Emission Control Warranty for California

Caterpillar Inc. (Caterpillar) warrants to the ultimate purchaser and each subsequent purchaser that new nonroad diesel engines (including Tier 1 and Tier 2 marine propulsion engines < 37 kW and Tier 1 through Tier 4 marine auxiliary engines < 37 kW, but excluding locomotive and other marine engines) operated and serviced in California, including all parts of their emission control system ("emission related components"), are:

1. Designed, built, and equipped so as to conform, at the time of sale, to all applicable regulations adopted by the California Air Resources Board (ARB).
2. Free from defects in materials and workmanship which cause the failure of an emission related component to be identical in all material respects to the component described in Caterpillar's application for certification for the warranty period.

Warranty Period

The warranty period shall be the period of years or hours of operation specified in the following table, whichever occurs first, after the date of delivery to the ultimate purchaser.

If your engine is certified as:	And its maximum power is:	And its rated speed is:	Then its warranty period is (whichever occurs first):
Variable speed or constant speed	kW < 19	Any speed	1,500 hours or two years
Constant speed	19 < kW < 37	3,000 rpm or higher	1,500 hours or two years
Constant speed	19 < kW < 37	Less than 3,000 rpm	3,000 hours or five years
Variable speed	19 < kW < 37	Any speed	3,000 hours or five years
Variable speed or constant speed	kW > 37	Any speed	3,000 hours or five years

Any warranted part that is scheduled for replacement as required maintenance is warranted for the period of time prior to the first scheduled replacement point for that part.

Any part repaired or replaced under warranty is warranted for the remainder of the warranty period.

Warranty Coverage

This Emission Control Warranty covers:

- All components whose failure would increase the engine's emissions of any pollutant, including
 - Fuel Metering System
 - Fuel Injection system
 - Air Induction System
 - Controlled hot air intake system
 - Intake manifold
 - Turbocharger systems
 - Charge air cooling systems
 - Exhaust Gas Recirculation (EGR) System
 - EGR valve body
 - EGR rate feedback and control system
 - Catalyst or Thermal Reactor System
 - Catalytic converter
 - Exhaust manifold
 - Particulate Controls
 - Traps, filters, precipitators, and any other device used to capture particulate emissions
 - Regenerators, oxidizers, fuel additive devices, and any other device used to regenerate or aid in the regeneration of the particulate control device
 - Control device enclosures and manifolding
 - Smoke Puff Limiters
 - Advanced Oxides of Nitrogen (NOx) Controls
 - Selective Catalyst Reduction
 - Reductant (urea/fuel) containers/dispensing systems

- Positive Crankcase Ventilation (PCV) System
 - PCV valve
 - Oil filler cap
- Miscellaneous Items Used in Above Systems
 - Vacuum, temperature, and time sensitive valves and switches
 - Electronic control units, sensors, solenoids, and wiring harnesses
 - Hoses, belts, connectors, assemblies, clamps, fittings, tubing, sealing gaskets or devices, and mounting hardware
 - Pulleys, belts and idlers
 - Emission control information labels
 - Any other part with the primary purpose of reducing emissions or that can increase emissions during failure without significantly degrading engine performance
- Components from any other system developed to control emissions
- Damages to other engine components caused by a failure under warranty of any warranted part.

This Emission Control Warranty does not cover components whose failure would not increase the engine's emissions of any pollutant.

Caterpillar Responsibilities

During the warranty period, if a defect in materials or workmanship is found which causes the failure of an emission related component to be identical in all material respects to the component as described in Caterpillar's application for certification, Caterpillar will provide the following at no charge through a Cat dealer or other source approved by Caterpillar:

- New, remanufactured, or repaired components (at Caterpillar's choice) required to correct the defect. Note: emission related components replaced under warranty become the property of Caterpillar.
- Reasonable or customary labor, during normal working hours, needed to correct the defect, including labor for removal and installation when necessary to make the repair

In an emergency, repairs may be performed at any service establishment, or by the user. Caterpillar will reimburse the user for their expenses including diagnostic charges for such emergency repair. These expenses shall not exceed Caterpillar's suggested retail price for all warranted emission related components replaced, and labor charges based on Caterpillar's recommended time allowance for the warranty repair and the geographically appropriate hourly labor rate. An emission related component not being available within 30 days or a repair not being complete within 30 days constitutes an emergency.

User Responsibilities

During the warranty period the user is responsible for the following:

- Providing proof of delivery date to the ultimate purchaser
- Parts shipping charges in excess of those that are usual and customary.
- Premium or overtime labor costs.
- Local taxes, if applicable.
- Costs to investigate complaints which are not caused by a defect in Caterpillar material or workmanship.
- Providing timely notice of a warrantable failure and promptly making the product available for repair. The warranty repairs should be completed in a reasonable amount of time, not to exceed 30 days.
- Presenting replaced emission related components and validated invoices at a place of business of a Cat dealer or other source approved by Caterpillar, as a condition of reimbursement.
- Proper maintenance of the engine, at the owner's expense, including all recommended maintenance and fluid changes at scheduled intervals, and use of proper fuel, oil, lubricants, coolant, and filters. Caterpillar recommends that you retain all receipts and records covering the maintenance on your engine, but cannot deny warranty solely for the lack of receipts and records or for your failure to ensure the performance of all scheduled maintenance.

Maintenance, replacement, or repair of the emission control devices and systems may be performed by any off-road engine repair establishment or individual using certified off-road engine parts. The user should ensure that such parts are equivalent in design and durability to genuine Cat parts. Use of non-genuine Cat parts does not invalidate the warranty. However, Caterpillar is not liable for parts that are not genuine Cat parts.

Limitations

In addition to any other limitations stated herein, Caterpillar is not responsible for failures of emission related components due to:

- Any use or installation that Caterpillar judges improper.
- Attachments, systems, accessories, components or parts not sold nor approved by Caterpillar
- The use of add-on or modified parts that are not exempted by the ARB.
- Abuse, neglect, vandalism, or improper engine maintenance or repair, including the installation of parts or assembled components in contaminated systems.
- Fire, accident, acts of God or other events beyond the control of Caterpillar
- User's delay in making the product available after being notified of a potential product problem.
- Unauthorized repairs or adjustments and unauthorized fuel setting changes.

Caterpillar is not responsible for damages to parts, fixtures, housings, attachments, and accessory items that are not part of the engine (including any products of other manufacturers packaged and sold by Caterpillar).

This warranty is in addition to Caterpillar's standard warranty, applicable to the off-road diesel engine product involved.

NEITHER THE FOREGOING EXPRESS WARRANTY NOR ANY OTHER WARRANTY BY CATERPILLAR, EXPRESS OR IMPLIED, IS APPLICABLE TO ANY ITEM CATERPILLAR SELLS THAT IS WARRANTED DIRECTLY TO THE USER BY ITS MANUFACTURER.

THIS WARRANTY IS EXPRESSLY IN LIEU OF ANY OTHER WARRANTIES, EXPRESS OR IMPLIED, INCLUDING ANY WARRANTY OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE. REMEDIES UNDER THIS WARRANTY ARE LIMITED TO THE PROVISION OF MATERIAL AND SERVICES, AS SPECIFIED HEREIN. CATERPILLAR IS NOT RESPONSIBLE FOR INCIDENTAL OR CONSEQUENTIAL DAMAGES.

Customer Assistance

Caterpillar aims to ensure that the Emission Control Systems Warranty is properly administered. In the event that you do not receive the warranty service to which you believe you are entitled under the Emission Control Systems Warranty, write: Caterpillar Inc., 100 N. E. Adams St., Peoria, IL USA 61629.

Federal Emission Control Warranty

Caterpillar Inc. (Caterpillar) warrants to the ultimate purchaser and each subsequent purchaser that new nonroad diesel engines and stationary diesel engines less than 10 liters per cylinder (including Tier 1 and Tier 2 marine engines < 37 kW, but excluding locomotive and other marine engines) operated and serviced in the United States and Canada, including all parts of their emission control systems ("emission related components"), are:

1. Designed, built, and equipped so as to conform, at the time of sale, with applicable emission standards prescribed by the United States Environmental Protection Agency (EPA) by way of regulation.
2. Free from defects in materials and workmanship in emission related components that can cause the engine to fail to conform to applicable emission standards for the warranty period.

Warranty Period

The warranty period shall be the period of years or hours of operation specified in the following table, whichever occurs first, after the engine is first placed into service.

If your engine is certified as:	And its maximum power is:	And its rated speed is:	Then its warranty period is (whichever occurs first):
Variable speed or constant speed	kW < 19	Any speed	1,500 hours or two years
Constant speed	19 < kW < 37	3,000 rpm or higher	1,500 hours or two years
Constant speed	19 < kW < 37	Less than 3,000 rpm	3,000 hours or five years
Variable speed	19 < kW < 37	Any speed	3,000 hours or five years
Variable speed or constant speed	kW > 37	Any speed	3,000 hours or five years

Any warranted part that is scheduled for replacement as required maintenance is warranted for the period of time prior to the first scheduled replacement point for that part.

Any part repaired or replaced under warranty is warranted for the remainder of the warranty period.

Warranty Coverage

This Emission Control Warranty covers:

- All components whose failure would increase the engine's emissions of any pollutant, including any engine parts related to the following systems:

1. Air-induction system
2. Fuel system
3. Ignition system
4. Exhaust gas recirculation systems

- The following parts are also covered:

1. Aftertreatment devices
2. Crankcase ventilation valves
3. Sensors
4. Electronic control units

- Components whose only purpose is to reduce emissions or whose failure will increase emissions without significantly degrading engine performance.

- Components from any other system developed to control emissions.

This Emission Control Warranty does not cover components whose failure would not increase the engine's emissions of any pollutant.

Caterpillar Responsibilities

During the warranty period, if a defect in materials or workmanship is found in an emission related component that can cause the engine to fail to conform to applicable emission standards, Caterpillar will provide the following at no charge through a Cat dealer or other source approved by Caterpillar:

- New, remanufactured, or repaired components (at Caterpillar's choice) required to correct the defect. Note: emission related components replaced under warranty become the property of Caterpillar.
- Reasonable or customary labor, during normal working hours, needed to correct the defect, including labor for removal and installation when necessary to make the repair.

In an emergency, repairs may be performed at any service establishment, or by the user. Caterpillar will reimburse the user for their expenses including diagnostic charges for such emergency repair. These expenses shall not exceed Caterpillar's suggested retail price for all warranted emission related components replaced, and labor charges based on Caterpillar's recommended time allowance for the warranty repair and the geographically appropriate hourly labor rate. An emission related component not being available within 30 days or a repair not being complete within 30 days constitutes an emergency.

User Responsibilities

During the warranty period the user is responsible for the following:

- Providing proof of date the engine was first placed into service.
- Parts shipping charges in excess of those that are usual and customary.
- Premium or overtime labor costs.
- Local taxes, if applicable.
- Costs to investigate complaints which are not caused by a defect in Caterpillar material or workmanship.
- Providing timely notice of a warrantable failure and promptly making the product available for repair. The warranty repairs should be completed in a reasonable amount of time, not to exceed 30 days.
- Presenting replaced emission related components and validated invoices at a place of business of a Cat dealer or other source approved by Caterpillar, as a condition of reimbursement.
- Proper maintenance of the engine, at the owner's expense, including all recommended maintenance and fluid changes at scheduled intervals, and use of proper fuel, oil, lubricants, coolant, and filters. Caterpillar recommends that you retain all receipts and records covering the maintenance on your engine, but cannot deny warranty solely for the lack of receipts and records or for your failure to ensure the performance of all scheduled maintenance.

Maintenance, replacement, or repair of the emission control devices and systems may be performed by any nonroad engine repair establishment or individual using certified nonroad engine parts. The user should ensure that such parts are equivalent in design and durability to genuine Cat parts. Use of non-genuine Cat parts does not invalidate the warranty. However, Caterpillar is not liable for parts that are not genuine Cat parts.

Limitations

In addition to any other limitations stated herein, Caterpillar is not responsible for failures of emission related components due to:

- Any use or installation that Caterpillar judges improper.
- Attachments, systems, accessories, components or parts not sold nor approved by Caterpillar.
- Abuse, neglect, vandalism, or improper engine maintenance or repair, including the installation of parts or assembled components in contaminated systems.
- Fire, accident, acts of God or other events beyond the control of Caterpillar.
- User's delay in making the product available after being notified of a potential product problem.
- Unauthorized repairs or adjustments and unauthorized fuel setting changes.

Caterpillar is not responsible for damage to parts, fixtures, housings, attachments, and accessory items that are not part of the engine (including any products of other manufacturers packaged and sold by Caterpillar).

This Emission Control Warranty is in addition to Caterpillar's standard warranty, applicable to the nonroad or stationary diesel engine product involved. Caterpillar is not responsible for damages to other engine components caused by a failure of an emission related component, unless otherwise covered by standard warranty.

NEITHER THE FOREGOING EXPRESS WARRANTY NOR ANY OTHER WARRANTY BY CATERPILLAR, EXPRESS OR IMPLIED, IS APPLICABLE TO ANY ITEM CATERPILLAR SELLS THAT IS WARRANTED DIRECTLY TO THE USER BY ITS MANUFACTURER.

THIS WARRANTY IS EXPRESSLY IN LIEU OF ANY OTHER WARRANTIES, EXPRESS OR IMPLIED, INCLUDING ANY WARRANTY OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE. REMEDIES UNDER THIS WARRANTY ARE LIMITED TO THE PROVISION OF MATERIAL AND SERVICES, AS SPECIFIED HEREIN. CATERPILLAR IS NOT RESPONSIBLE FOR INCIDENTAL OR CONSEQUENTIAL DAMAGES.

Customer Assistance

Caterpillar aims to ensure that the Emission Control Warranty is properly administered. In the event that you do not receive the warranty service to which you believe you are entitled under the Emission Control Warranty, write: Caterpillar Inc., 100 N. E. Adams St., Peoria, IL USA 61629.

Authorized dealers are recommended for maintenance and repair work as they are staffed with trained personnel, proper tools, and are aware of the latest maintenance methods and procedures. Owners and others who desire to perform their own work should obtain current service information from their Cat dealer.