

Diesel Engine Lubricant Evaluations

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Caterpillar 1M-PC Procedure

Specifications

This procedure covers specification CF & CF-2 API categories.

Objective

The objective of this procedure is to evaluate the performance of crankcase lubricants with respect to piston deposits, ring sticking, ring and cylinder wear as well as piston, ring and liner scuffing.

Field service simulated

High-speed, supercharged off-highway heavy-duty diesel engine service is simulated.

Procedure fixture

A Caterpillar 1Y73 single-cylinder indirect injection diesel procedure engine with a two-valve arrangement having a 5.125 in. bore and a 6.5 in. stroke resulting in a displacement of 134.1 cubic inches is used. The compression ratio is 16.4:1 and this engine uses rectangular rings.

Procedure parameters

Procedure parameters are: 1800 rpm, 42 bhp, 141 bmep, 5850 btu/min fuel input, 190°F coolant temperature, 205°F oil temperature, 255°F inlet air temperature at 53" hg and 125 grains/lb, 23.5:1 air-fuel ratio for 120 hours.

Procedure parts

Procedure parts include: liner (1Y3995), piston (1Y3589) and ring set (1Y3588), all meeting Caterpillar's new "3L" quality specifications.

Procedure fuel

Reference fuel with a sulfur specification of 0.38–0.42 mass % and an API gravity specification of 33–35° is used for this procedure.

Procedure parts evaluated

Piston, rings and liner are evaluated. The piston is rated by the CRC (Coordinating Research Council) demerit procedure.

Lubricant analysis

Lubricant analysis includes new oil viscosity only.

Pass/fail criteria

The pass/fail criteria are no ring sticking, no piston, ring, or liner scuffing. Weighted total demerits ≤ 240 , top groove fill $\leq 70\%$, and loss of side clearance ≤ 0.0005 ".

CF-2

Only the WTD rating applies using the following location factors.

<u>Ring Grooves</u>	<u>Location Factor</u>
1	1.0
2	0.5
3	0
4	0
 <u>Lands</u>	
2	0.75
3	0
4	0

Limit for WTD is 100.

Caterpillar 1K Procedure

Specifications

This procedure is included in API specifications CF-4, CH-4 and CI-4.

Objective

The objective of this procedure is to evaluate the performance of crankcase lubricants with respect to piston deposits, ring sticking, ring and cylinder wear, piston, ring and liner scuffing, as well as oil consumption.

Field service simulated

High-speed turbocharged heavy-duty diesel engine service is simulated.

Procedure fixture

A Caterpillar 1Y540 single-cylinder direct injection diesel procedure engine with a four-valve arrangement having a 5.4 in. bore and a 6.5 in. stroke resulting in a displacement of 148.8 cubic inches is used for this procedure. Compression ratio is 14.5:1. A keystone top ring and a rectangular second ring are used.

Procedure parameters

Procedure parameters are: 2100 rpm, 70 bhp, 1800 bmep, 7990 btu/min fuel input, 200°F coolant temperature, 225°F oil temperature, 260°F inlet air temperature at 71" hg and 125 grains/lb, 29:1 air fuel ratio for 252 hours.

Procedure parts

Procedure parts include: liner (1Y3555G), piston (1Y0727), and ring set (1Y0728), all meeting Caterpillar's new "3L" quality specifications.

Procedure fuel

Reference fuel with a sulfur specification of 0.38 – 0.42 mass % and an API gravity specification of 33 – 35° is used.

Procedure parts evaluated

Piston, rings and liner are evaluated. The piston is rated by the CRC (Coordinating Research Council) demerit procedure.

Lubricant analysis

Viscosity, TBN, wear metals, and a check for fuel dilution are conducted.

Pass/fail criteria

Based on reference oil 809, the following acceptance limits apply: no piston, ring or liner distress, no stuck rings allowed. Based upon the time period that each procedure completed, the appropriate parameter adjustment factor is added to the procedure result.

For a first procedure run, the adjusted results are compared to the above first procedure limits. For a two- or three-procedure program, the average of the adjusted procedure results is compared to the appropriate pass limits.

CH-4, CI-4

Requirement	1st Procedure	2nd Procedure	3rd Procedure
WDK (Demerits)	332	347	353
TGF (%)	24	27	29
TLHC (%)	4	5	5
BSOC Avg. g/kW-hr	≤ 0.5	≤ 0.5	≤ 0.5
EOTOC g/kw hr	≤ 0.27	≤ 0.27	≤ 0.27

CF-4

Requirement*	2nd Procedure	3rd Procedure	4th Procedure
WDK (Demerits)	332	339	342
TGF (%)	24	26	27
TLHC (%)	4	4	5
BSOC Avg. g/kW-hr	0.5	0.5	0.5
EOTOC g/kw hr	0.27	0.27	0.27

*Minimum of 2 procedures required

Caterpillar 1N Procedure

Specifications

This procedure covers the CG-4 API category.

Objective

The objective of this procedure is to evaluate the performance of crankcase lubricants with respect to piston deposits, ring sticking, ring and cylinder wear, piston, ring and liner scuffing, as well as oil consumption, with lower sulfur fuel.

Field service simulated

High-speed turbocharged on-highway heavy-duty diesel engine service is simulated.

Procedure fixture

A Caterpillar 1Y540 single-cylinder direct-injection diesel procedure engine with a four-valve arrangement having a 5.4 in. bore and a 6.5 in. stroke resulting in a displacement of 148.8 cubic inches is used for this procedure. Compression ratio is 14.5:1. A keystone top ring and rectangular second ring are used.

Procedure parameters

Procedure parameters: 2100 rpm, 70 bhp, 1800 bmep, 7990 btu/min fuel input, 200°F coolant temperature, 225°F oil temperature, 260°F inlet air temperature at 71" hg and 125 grains/lb, 29:1 air fuel ratio for 252 hours.

Procedure parts

Procedure parts include: liner (1Y3998), piston (1Y0727), and ring set (1Y0728), all meeting Caterpillar's new "3L" quality specifications.

Procedure fuel

Reference fuel with a sulfur specification of 0.03 – 0.05 mass % and an API gravity specification of 33 – 35° is used.

Procedure parts evaluated

Piston, rings and liner are evaluated. The piston is rated by the CRC (Coordinating Research Council) demerit procedure.

Lubricant analysis

Lubricant analysis includes viscosity, TBN, wear metals, and a check for fuel dilution.

Pass/fail criteria

Based on reference oil 1004, the following acceptance limits apply:

	1st Procedure	2nd Procedure	3rd Procedure
WDK (Demerits)	286.2	311.7	323
TGF (%)	20	23	25
TLHC (%)	3	4	5
BSOC Avg. (g/kW-hr)	≤ 0.5	≤ 0.5	≤ 0.5

No piston or ring liner distress and no stuck rings are allowed.

Based upon the time period that each procedure completed, the appropriate parameter adjustment factor is added to the procedure result. For a first procedure run, the adjusted results are compared to the above first procedure limits. For a two- or three-procedure program, the average of the adjusted procedure results is compared to the appropriate pass limits.

Caterpillar 1P Procedure

Specifications

This procedure follows specification CH-4.

Objective

The objective of this procedure is to evaluate the performance of crankcase lubricants with respect to piston deposits, ring sticking, ring and cylinder wear, piston, ring and liner scuffing, as well as oil consumption, with a steel top, aluminum skirt, and two-piece piston.

Field service simulated

High-speed turbocharged heavy-duty diesel engine service is simulated.

Procedure fixture

The procedure fixture is a Caterpillar 1Y3700 single-cylinder direct-injection diesel procedure engine with a four-valve arrangement having a 5.4 in. bore and a 6.5 in. stroke resulting in a displacement of 148.8 cubic inches. Compression ratio is 16.25:1. Keystone top ring and second ring are used. The top ring is closer to the piston top than the 1K/1N. The engine features overhead cam and electronic injection control.

Procedure parameters

Procedure parameters: 1800 rpm, 55 kW, 185 g/min fuel rate, 90°C coolant temperature, 130°C oil temperature, 60°C air temperature, at 272 kPa and 17.8 g/kg water vapor for 360 hours.

Procedure parts

Procedure parts include: liner (1Y3805), iron piston crown (1Y3658), aluminum skirt (1Y3400) and ring set (1Y3802 top, 1Y3803 second, 1Y3804 oil), all meeting Caterpillar's "3L" quality specifications.

Procedure fuel (forecasted)

Reference fuel with a sulfur specification of 0.03 – 0.05 mass % and an API gravity specification of 32 – 36° is used.

Procedure parts evaluated

Piston, rings and liner are evaluated. The piston is rated by the CRC (Coordinating Research Council) demerit procedure.

Lubricant analysis

Viscosity, TBN, TAN, wear metals, and a check for fuel dilution are performed.

Pass/fail criteria

No piston or ring liner distress and no stuck rings are allowed.

Based upon the time period that each procedure completed, the appropriate parameter adjustment factor is added to the procedure result. For a first procedure run, the adjusted results are compared to the above first procedure limits. For a two- or three-procedure program, the average of the adjusted procedure results are compared to the appropriate pass limits.

	1st Procedure	2nd Procedure	3rd Procedure
WDP	350	378	390
TGC	36	39	41
TLC	40	46	49
Avg. OC g/h	12.4	12.4	12.4
EOTOC, g/h	14.6	14.6	14.6

Caterpillar 1R Procedure

Specifications

This procedure follows specification WWHD-1, CI-4.

Objective

The objective of this procedure is to evaluate the performance of crankcase lubricants with respect to piston deposits, oil control, and scuffing resistance for ferrous pistons.

Field service simulated

High-speed turbocharged heavy-duty diesel engine service is simulated.

Procedure fixture

The 1R procedure is run in a high-speed four-stroke cycle Caterpillar 1Y3700 single-cylinder procedure engine. The 1Y3700 procedure engine is equipped with the following features: two-piece articulated piston with steel crown and aluminum skirt, mid-supported low distortion cylinder liner, gear-driven overhead cam, high-pressure electronically controlled fuel injection system, and a high-temperature oil system.

Procedure parameters

Procedure parameters: 1800 rpm, 68 kW, 240 g/min fuel rate, 120°C oil temperature, and 17.8 g/kg water vapor for 504 hours.

Procedure parts

Procedure parts include: liner (1Y3805), piston crown (145-6744), piston skirt (132-6663), top ring (132-6662), 2nd ring (139-9126), oil ring (7E2990), cooling jet (1Y4011), jet aim fixture (1Y3980), ECM 13 deg chip (154-8353).

Procedure fuel

Reference fuel with a sulfur specification of 0.03 – 0.05 mass % and an API gravity specification of 32 – 36° is used for this procedure.

Procedure parts evaluated

Piston, rings and liner are evaluated. The piston is rated by the CRC (Coordinating Research Council) demerit procedure.

Lubricant analysis

Lubricant analysis includes viscosity, TBN, TAN, wear metals, and fuel dilution.

Pass/fail criteria

No piston or ring liner distress and no stuck rings are allowed.

DHD-1

Requirement	1st Procedure	2nd Procedure	3rd Procedure
WDR	397	416	440
TGC	40	42	44
TLC	37	42	46
Initial OC g/h	13.1	13.1	13.1
EOTOC, g/h	1.5 x Initial	1.5 x Initial	1.5 x Initial

CI-4

Requirement	1st Procedure	2nd Procedure	3rd Procedure
WDR	382	396	402
TGC	52	57	
TLC	31	35	36
Initial OC g/h	13.1	13.1	13.1
EOTOC, g/h	BTOC+1.8	BTOC+1.8	BTOC+1.8

Based upon the time period that each procedure completed, the appropriate parameter adjustment factor is added to the procedure result. For a first procedure run, the adjusted results are compared to the above first procedure limits. For a two- or three-procedure program, the average of the adjusted procedure results are used.

Caterpillar C13 Lubricant Procedure

This 500-hour procedure uses a Caterpillar C13 engine with all steel pistons, operated at 1800 RPM and 1200 grams per minute fuel rate to evaluate the performance of crankcase lubricants with regard to piston deposits and oil consumption. The procedure is proposed for inclusion in the PC-10 category.

Mack T8

Specifications

This procedure follows specifications MACK EO-L, EO-L Plus, EO-M, EO-M Plus, API CG-4.

Objective

This objective of this procedure is to evaluate the soot handling capability of engine crankcase oil with regard to viscosity.

Field service simulated

Field service simulated is heavy-duty, stop-and-go operation, and high-soot loading.

Procedure fixture

The procedure engine is a Mack E7-350, fixed time, in-line six-cylinder configuration 11GBA77623, open-chamber, four-stroke, turbocharged, intercooled, compression ignition engine. The bore and stroke are 4-7/8 x 6-1/2 inches. The engine is rated at 350 bhp @ 1800 rpm.

Procedure parameters

Each procedure is 250 hours under constant rated speed and load conditions with controlled water out, fuel, intake air and intake manifold temperatures. Exhaust backpressure and inlet air restriction levels are also controlled. Between procedures, the engine is flushed for 2 hours with the next procedure oil.

Procedure parts evaluated

Oil filter plugging is evaluated.

Used lubricant analysis

Oil samples are taken every 25 hours and analyzed for kinematic viscosity at 100°C.

Pass/fail criteria

The pass/fail criteria include: maximum viscosity increase at 3.8% soot – 11.5, 12.5 & 13.0 cSt for 1,2,3 procedures; oil filter plugging < 20 psig; and relative viscosity \leq 2.1 for the T-8E @ 4.8% soot.

Mack T8E

This procedure is the same as Mack T8, but runs 300 hours versus 250 hours, used in category CH-4, CI-4, and Mack EON Premium Plus.

Mack T8A

This procedure is the same as T8 but runs only 150 hours. It is a replacement procedure for the Mack T7.

Pass/fail criteria

The pass/fail limit is < 0.20 centistokes per hour @ 100–150 hours.

Roller Follower Wear Procedure

Specifications

API CG-4, CH-4, CI-4.

Objective

The objective of this procedure is to determine the effect of lubricating oils on roller follower axle wear.

Field service simulated

The engine is used in several commercial and military applications.

Procedure fixture

The procedure engine is a General Motors 6.5 liter indirect injected diesel. The engine is rated at 160 horsepower at 3400 rpm.

Procedure parameters

The engine is run at 1000 rpm with near maximum load for 50 hours without an oil change. Make-up oil is added at 25 hours. Oil gallery and coolant out temperatures are controlled to 120°C.

Procedure parts evaluated

New roller followers are installed at the beginning of each procedure. At the end of each procedure, the roller follower axles are removed and their wear is measured using a linear profilometer.

Used lubricant analysis

Viscosity at 40°C and 100°C, TBN, wear and additive metals are analyzed as specified. Samples are taken at 0, 25, and 50 hours.

Pass/fail criteria

The pass/fail limits for wear on the roller follower axle have been set at 11.4 microns (0.45 mils) for CG-4 and 7.6 microns (0.30 mils) for CH-4 and CI-4.

Cummins ISB

This 350-hour procedure uses a Cummins ISB engine and is used to evaluate a crankcase lubricant's ability to reduce camshaft lobe and sliding cam follower wear. After an internal 100 hours of steady-state operation at 1600 rpm to accumulate 4% soot in the oil, the engine is operated for 250 hours on a 28-second cycle simulating front and loader operation. This procedure is proposed for inclusion in the PC-10 category.

Cummins M11 EGR

Specifications

This procedure is for CH-4, CI-4 and CES-20078.

Objective

The objective of this procedure is to determine the effectiveness of lubricating oils at reducing "soot" related wear of overhead components in engines with exhaust gas recirculation.

Field service simulated

Heavy-duty on-highway trucking operations after 2002 are simulated.

Procedure fixture

The procedure engine is a modified Cummins ISM 425 engine rated at 425 bhp and 1800 rpm, with EGR.

Procedure parameters

This 300-hour engine procedure evaluates overhead wear, filter plugging, and sludge. One hundred fifty hours are spent at 1600 rpm over fueled and one hundred fifty hours at 1800 rpm, over fueled and retarded timing, in alternating 50-hour segments.

Procedure parts evaluated

- Engine crossheads – weight loss
- Engine oil filter – plugging via delta pressure
- Engine valve cover and oil pan – sludge rating

Used lubricant analysis

Used lubricant analysis includes viscosity at 40°C and 100°C, TBN, TAN, wear and additive metals, samples every 25 hours.

Pass/fail criteria

The pass/fail criteria are as follows:

- Kinematic crosshead weight loss: 20 mg max
- Oil filter plugging: 275 kPa max
- Average sludge: 7.8 merits min

Cummins ISM

This 200-hour procedure uses a Cummins ISM engine and essentially is intended as a replacement procedure for the M-11EGR, using newer hardware. The engine has variable geometry turbocharging, production EGR coolers and EGR valve, and evaluates a lubricant's effectiveness at reducing soot-related overhead wear, sludge, and filter plugging. It is proposed for inclusion in the PC-10 category as well as being an alternative to the M-11 EGR for the CI-4 category.

Mack T10

Specifications

This procedure is included in API CI-4 and Mack E-ON Premium Plus.

Objective

This procedure evaluates an oil's ability to minimize cylinder liner, piston ring and bearing wear in engines with exhaust gas recirculation.

Field service simulated

Heavy-duty on-highway truck operations after 2002 are simulated.

Procedure fixture

The procedure engine is a modified Mack E7 E-Tech 460 rated at 460 bhp and 1800 rpm, with EGR.

Procedure parameters

This is a 300-hour engine procedure. The first 75 hours are at rated speed and power to generate soot. Then, the last 225 hours are over-fueled at peak torque rpm to maximize the wear rates on the rings and liners.

Procedure parts evaluated

Piston ring wear, cylinder liner wear, lead content, oil consumption, and oxidation are evaluated.

Used oil analysis

Used oil analysis includes viscosity @ 100°C, soot, TBN, TAN, lead content, FTIR oxidation.

Pass/fail criteria

The pass/fail criteria include:

Mack merits	1000 min
Avg. cylinder wear	32 microns max
Avg. ring weight loss	158 mg max
End of procedure lead level	35 ppm max
Delta level 250–300 hrs	14 ppm max
Oil consumption	645 g/hr max

Mack T-11

This 252-hour procedure uses a mack prototype E-Tech engine operation at 1800 rpm with non-condensing cooled exhaust gas recirculation and production 2002 heads, injectors and pistons, to evaluate a lubricant's ability to limit viscosity increase with high soot loading. This procedure is part of Mack engine oil specification EOM Plus 03, CI-4 Plus and will be included I PC-10.

Mack T-12

This 300-hour procedure uses much the same hardware as the T10 procedure, but now has a variable geometry turbocharger and production EGR cooling heat exchangers. To simulate 2007 engine operation, EGR rates are increased significantly from the T-10 levels. Procedure objectives are the same, to minimize cylinder liner, ring and bearing wear. This procedure is proposed for inclusion in the PC-10 category.

Engine Oil Aeration Procedure

Specifications

This procedure follows specifications API CG-4, CH-4, and CI-4.

Objective

The objective of this procedure is to determine the effectiveness of engine lubricating oils at minimizing the amount of air entrainment.

Field service simulated

The engine is used in large pickups and medium-duty trucks. The procedure simulates high-speed, high-load applications.

Procedure fixture

The procedure engine is a 1994 International Truck 7.3 liter V-8, four-stroke, turbocharged, compression ignition engine using the HEUI (hydraulically actuated, electronically controlled, unit injectors) fuel injection system. The engine is rated at 215 bhp at 3000 rpm.

Procedure parameters

Each procedure is run for 20 hours at rated speed and maximum load conditions with controlled water out, fuel, and inlet air temperatures and intake air restriction. Between procedures, the engine is flushed twice, for one hour each, with the next procedure oil.

Procedure evaluation

At 0, 5, and 20 procedure hours, the oil is evaluated to determine the amount of entrained air in the oil.

Used lubricant analysis

The lubricant is analyzed for wear metals at 0 and 20 hours.

Pass/fail criteria

At 20 hours, the maximum allowable amount of air entrained in the oil is 8.0% for CH-4 and CI-4 and 10.0% for CG-4.