Gasoline Engine Lubricant Evaluations

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Sequence L38 (ASTM D 5119)

Specifications
API categories SE/SF/SG/SJ/ILSAC GF-1 & GF-2, CD-II/CE/CF, MIL-L-46152E, MIL-L-2104F, MIL-L-21260D, MIL-L-46167B. (Some of these are now obsolete.)

Objective
The objective of this procedure is to evaluate a lubricant's performance in combating copper/lead/tin bearing corrosion and to measure viscous shear stability.

Field service simulated
High-temperature, corrosive service is simulated. Copper/lead/tin bearings. Field service correlation has not been established.

Procedure fixture
A 42.5 CID carbureted, single cylinder, spark ignition, CLR oil procedure engine operated with an external oil heater circuit.

Procedure parameters
The engine runs 40 hrs @ 35.5 BMEP using a leaded ISO-octane fuel. The engine is shut down each 10 hours for an oil level check. Procedure speed is 3150 rpm and the oil temperature is raised to 290°F (143°C) using an external oil heater circuit.

Procedure parts evaluated
The engine is inspected for sludge and varnish deposits and the connecting rod bearing weight loss is measured.

Used lubricant analysis

- Kinematic viscosity
- Neutralization number
- Multi-grade oils require a 10 hr stripped viscosity

Pass/fail criteria
API SH/ILSAC GF-1 & GF-2, 40 Mg weight loss max, stripped viscosity must stay in grade.

Sequence IID (ASTM D 5844)

This procedure is

Specifications
API categories CC/SE/SF/SG/SH/ILSAC GF-1 & GF-2, MIL-L-46152E, MIL-L-2104E, MIL-L-21260D, MIL-L-46167B. (Some of these procedures are now obsolete.)

Objective
The objective of this procedure is to evaluate a lubricant's performance in combating internal engine corrosion, which can cause improper functioning of hydraulic valve lifters and oil pump relief valves.

Field service simulated
Short trip service under typical winter conditions**.**

Procedure fixture
A 1978 350 C.I.D. Oldsmobile V-8 gasoline engine, equipped with an external oil sump cooler, blowby gas condenser, and coolant jacketed rocker covers.

Procedure parameters
Using leaded gasoline, the engine is operated with a rich air/fuel mixture for 30 hours at 1500 rpm, 25 bhp. The first 28 hours are run with cool oil and jacket temperatures. Hours 28–30 have the oil and jacket temperatures increased slightly to accelerate the corrosion tendency. For hours 30–32, the engine is run at high speed and temperatures to end the corrosion process. Total procedure length is 32 hours.

Procedure parts evaluated
Pushrods, valve lifter components, oil pump relief valves.

Used lubricant analysis
An operational check for glycol contamination is performed.

Pass/fail criteria
For SH/MIL-L-46152, there is an 8.5 minimum rating.

Sequence IIIE (ASTM D 5533)

This procedure is

Specifications
API categories SG/SJ/ILSAC GF-1 & GF-2, MIL-L-46152E, MIL-L-2104F, MIL-L-21260D, MIL-L-47167B, ACEA, A1-96, A2-96. A3-96. (Some now obsolete.)

Objective
The objective of this procedure is to evaluate a lubricant's performance in combating high-temperature oxidation and in preventing cam lobe-flat tappet lifter wear.

Field service simulated
High-speed turnpike service under relatively high ambient conditions is simulated.

Procedure fixture
A 1986, 231 C.I.D. Buick V-6 gasoline engine, equipped with an external oil sump cooler and coolant jacketed rocker covers is used.

Procedure parameters
Using leaded gasoline, the engine runs a 4-hour break-in schedule, then operates at 67.8 bhp, 3000 rpm, and 300°F (149°C) oil temperature for 64 hours interrupted at 8 hour intervals for oil level checks.

Procedure parts evaluated
Inspect rocker covers and internal baffles for sludge; rate piston deposits and varnish; measure cam lobe and lifter for wear.

Used lubricant analysis
Compare kinematic viscosity increase to a new oil baseline (% increase).

Pass/fail criteria for SG

PARAMETER	PASS LIMIT
Hours to 375% viscosity increase	64 minimum
Average sludge rating, minimum	9.2
Piston skirt varnish, minimum	8.9
Oil ring land deposits, minimum	3.5
Cam & lifter wear, maximum	
• Average, µm	30
• Maximum per position, µm	64
Stuck compression rings with ring land less than 3.5	NONE

Sequence IIIF

Specifications
ILSAC GF-3.

Objective
The objective of this procedure is to evaluate a lubricant's performance in combating high-temperature oxidation and in preventing sliding-contact lifter and cam wear.

Field service simulated
High-speed service under relatively high ambient conditions is simulated.

Procedure fixture
A 1996/1997 231 C.I.D. (3800 CC) Series II General Motors V-6 fuel-injected gasoline engine, equipped with an external oil sump cooler.

Procedure parameters
Using unleaded gasoline, the engine runs a 10-minute initial oil leveling procedure followed by a 15-minute slow ramp up to speed and load conditions. It then operates at 100 bhp, 3600 rpm, and 155°C oil temperature for 80 hours, interrupted at 10-hour intervals for oil level checks.

Procedure parts evaluated
Inspect all six pistons for deposits and varnish; measure cam lobes and lifters for wear.

Used lubricant analysis
Compare kinematic viscosity increase at 40°C to a new oil baseline (% increase) every 10 hours. Wear metals (Cu, Pb, Fe) are also evaluated at this interval.

Pass/fail criteria

Parameter	Pass Limit
Viscosity increase	275%
Average piston skirt varnish	9.0 min
Weighted piston deposits	4.0 min
Average cam-plus-lifter wear	20 µm max
Stuck rings	None
Oil consumption	5.2 L max for NOACK ≤ 15% 6.5 L max for NOACK ≥ 15%
MRV @ EOT	Report only

Sequence IIIG

Specifications
API Category SM, ILSAC category GF-4.

Objective
The objective of this procedure is to measure oil thickening and piston deposits under high-temperature conditions and to provide information about valve train wear.

Field service simulated
This procedure simulated high-speed service under relatively high ambient conditions.

Procedure fixture
A 1996/1997 231 C.I.D. (3800 CC) Series II General Motors V-6 fuel-injected gasoline engine is used.

Procedure parameters
Using unleaded gasoline, the engine runs a 10-minute initial oil leveling procedure followed by a 15-minute slow ramp up to speed and load conditions. It then operates at 125 bhp, 3600 rpm, and 150°C oil temperature for 100 hours, interrupted at 20-hour intervals for oil level checks.

Procedure parts evaluated
At the end of the procedure, all six pistons are inspected for deposits and varnish. Cam lobes and lifters are measured for wear.

Used lubricant analysis
Compare kinematic viscosity increase at 40°C to a new oil baseline (% increase) every 20 hours. Wear metals (Cu, Pb, Fe) are also evaluated at this interval.

Pass/fail criteria

Parameter	Pass Limit
Viscosity increase	150%
Weighted piston deposits	3.5 minimum
Average cam-plus-lifter wear	60 µm maximum
Hot stuck rings	None
Oil consumption	4.65 L, max

Sequence IIIGA

Specifications
API Category SM, ILSAC category GF-4.

Objective
The objective of this procedure is to determine the cold-temperature viscosity performance on an end-of engine oil sample.

Field service simulated
This procedure simulated high-speed service under relatively high ambient conditions.

Procedure fixture
A 1996/1997 231 C.I.D. (3800 CC) Series II General Motors V-6 fuel-injected gasoline engine is used.

Procedure parameters
Using unleaded gasoline, the engine runs a 10-minute initial oil leveling procedure followed by a 15-minute slow ramp up to speed and load conditions. It then operates at 125 bhp, 3600 rpm, and 150°C oil temperature for 100 hours, interrupted at 20-hour intervals for oil level checks.

Procedure parts evaluated
None.

Used lubricant analysis
Cold crank simulator and apparent viscosity are run on the end-of-procedure sample.

Pass/fail criteria

Parameter	Pass Limit
MRV @ EOT	60,000 cP max (original grade or next highest)
Yield Stress	‹ 35 Pa

Sequence IVA (ASTM D 6891)

Specifications
API Category SL/SM and ILSAC GF-3/GF-4.

Objective
The objective of this procedure is to evaluate a lubricant's performance in preventing camshaft lobe wear in an overhead camshaft engine. This procedure replaces the VE procedure in this respect.

Field service simulated
The field service simulated is taxicab, light delivery truck, or commuter service.

Procedure fixture
The procedure fixture is a 1994 Nissan KA24E 2.4-liter, water-cooled, fuel-injected engine, four-cylinder in-line, overhead camshaft with two intake valves and one exhaust valve per cylinder.

Procedure parameters
This is a 100-hour procedure involving 100 hourly cycles, each cycle consisting of two operating modes (stages). Unleaded Haltermann KA24E Green fuel is used.

	Stage I	Stage II
Time, minutes	50	10
Engine Speed, rpm	800	1500
Engine Torque, N-m	25	25
Oil Cylinder Head Temp, °C	49	59
Coolant Temperature, °C	50	55

Procedure parts evaluated
The twelve cam lobes are each measured at seven locations, using a surface profilometer for the measurement of maximum depth of wear. The wear on all seven positions of each lobe are added, then all twelve lobes are averaged for the wear result. This result is the primary evaluation for the procedure.

Used lubricant analysis
The used oil at 100 hours is evaluated for kinematic viscosity, fuel dilution, and wear metals (Fe, Cu).

Pass/fail criteria
For SL and ILSAC GF-3 level of performance:

PARAMETER	PASS LIMIT
Average cam wear	120 µm max

For SM and ILSAC GF-4 level of performance:

PARAMETER	PASS LIMIT
Average cam wear	90µm max

Sequence VD

Specifications
Obsolete API CATEGORIES SE/SF, MIL-L-46152B, MIL-L-2104D, MIL-L-21260, MIL-L-46167A.

Objective
The objective of this procedure is to evaluate a lubricant's performance in combating sludge and varnish formation and preventing valve train wear in a modern overhead camshaft engine.

Field service simulated
Taxicab service is simulated.

Procedure fixture
A carbureted Ford 2.3 liter gasoline engine, four-cylinder, overhead camshaft, sliding followers, a blowby condenser, EGR, PCV, and camshaft baffle is used.

Procedure parameters
A 192-hour procedure involving 48 cycles, each cycle consisting of three operating modes (stages). Unleaded Phillips "J" fuel is used, and engine blowby is intentionally increased**.**

	STAGE 1	STAGE 2	STAGE 3
Time, minutes	120	75	45
Engine speed, rpm	2500	2500	750
Load, bhp	33.5	33.5	1.0
Oil Temp, °F	175	187	120
Coolant Temp, °F	135	155	120

Procedure parts evaluated
Inspect sludge deposits on rocker cover, front seal housing, oil pan, valve deck, and block underside. Varnish on piston skirts, rocker cover, cam baffle, cylinder walls, and oil pan is rated. Cam lobe wear and weight loss of follower arms is measured.

Used lubricant analysis

- Kinematic viscosity
- Iron content
- Copper content
- Silicon content
- Fuel dilution

Pass/fail criteria
For SF level of performance:

PARAMETER	PASS LIMIT
Sludge	9.4
Varnish	6.6
Piston skirts	6.7
Cam lobe wear	
• Average, mils	1.0
• Maximum, mils	2.5

Sequence VE (ASTM D 5302)

Specifications
API Category SG/SH/ILSAC GF-1 & GF-2, MIL-L-21260D, MIL-L-46167B.

Objective
The objective of this procedure is to evaluate a lubricant's performance in combating sludge and varnish formation and preventing valve train wear in a modern overhead camshaft engine. In comparison to the VD procedure, sludging tendency is increased and wear performance is better discriminated.

Field service simulated
Moderate temperature taxicab service / urban and suburban delivery service / job commuting service is simulated.

Procedure fixture
A fuel-injected Ford 2.3-liter gasoline engine, four-cylinder, sliding followers, overhead camshaft, coolant-jacketed rocker cover, and camshaft baffle.

Procedure parameters
A 288-hour procedure involving 72 cycles, each cycle consisting of three differing operating specifications (stages). Unleaded Phillips "J" fuel is used, and engine blowby is intentionally increased. Rocker cover jacket temperature is cycled.

	Stage 1	Stage 2	Stage 3
Time, minutes	120	75	450
Engine Speed, rpm	2500	2500	750
Load, bhp	33.5	33.5	1.0
Oil Temp, °F	155	210	115
Coolant Temp, °F	125	185	115
Rocker Cover Temp, °F	85	185	85

Procedure parts evaluation
Inspect sludge and varnish deposits on rocker cover, cam baffle, oil pan, and front seal housing. Rate varnish on piston skirts and cylinder walls. Inspect for "hot" stuck piston compression rings. Rate clogging of oil pump screen, piston oil rings, and camshaft oil feed holes. Measure cam lobe wear and weight loss of follower arms.

Used lubricant analysis
- Kinematic viscosity
- Iron content
- Copper content
- Silicon content
- Pentane insolubles
- Fuel dilution

Pass/fail criteria
For SG level of performance:

PARAMETER	PASS LIMIT *
Average engine sludge, minimum	9.0
Rocker cover sludge, minimum	7.0
Average engine varnish, minimum	4.61
Piston skirt varnish, minimum	6.5
Average cam wear, (MILS) maximum	5.0
Maximum cam wear, (MILS) maximum	15.0
Oil ring clogging, % maximum (Report only, limit waived)	15
Oil screen clogging, % maximum	20
Hot stuck compression rings	NONE

* After industry corrections and laboratory adjustments are applied.

Sequence VG (ASTM D 6593)

Specifications
API Category SL/SM and ILSAC GF-3/GF-4.

Objective
The objective of this procedure is to evaluate a lubricant's performance in combating sludge and varnish formation in a modern engine. This procedure replaces the VE procedure in this respect.

Field service simulated
Moderate temperature taxicab service / urban and suburban delivery service / job commuting service is simulated.

Procedure fixture
A fuel-injected 2000 Ford 4.6-liter gasoline engine, eight-cylinder, rolling followers, coolant-jacketed rocker covers and camshaft baffles.

Procedure parameters
A 216-hour procedure involving 54 cycles, each cycle consisting of three differing operating specifications (stages). Unleaded Haltermann SVGM2 fuel is used, and engine blowby is intentionally increased. Rocker cover jacket temperature is cycled.

	Stage 1	Stage 2	Stage 3
Time, minutes	120	75	45
Engine Speed,rpm	1200	2900	700
Load, Manifold Abs. Pres., kPa	69	66	Record
Oil Temp, °C	68	100	45
Coolant Temp, °C	57	85	45
Rocker Cover Temp, °C	29	85	29

Procedure parts evaluated
Inspect rocker arm covers, cam baffles, timing chain cover, oil pan baffle, oil pan and valve decks for sludge. Inspect piston skirts and cam baffles for varnish. Evaluate oil pump screen sludge and debris and oil ring clogging. Inspect for “hot” and “cold” stuck piston compression rings. Measure roller follower pin wear and ring gap increase.

Used lubricant analysis

- Kinematic Viscosity
- Iron content
- Copper content
- Aluminum content
- Lead content
- Tin content
- Silicon content
- Pentane insolubles
- Fuel dilution
- Total base number

Pass/fail criteria
For SL/SM and ILSAC GF-3/GF-4 level of performance:

PARAMETER	PASS LIMIT
Average engine sludge	7.8 min
Rocker cover sludge	8.0 min
Average engine varnish	8.9 min
Average piston skirt varnish	7.5 min
Oil screen sludge	20% max
Hot stuck rings	None
Oil screen debris	Rate and report
Oil ring clogging	Rate and report
Cold stuck rings	Rate and report
Follower pin wear, avg.	Rate and report
Ring gap increase, avg.	Rate and report

Sequence VIA (ASTM D 6202)

Specifications
API category ILSAC GF-2

Objective
The objective of this procedure is to measure the effects of engine oil on the fuel economy of gasoline engine passenger cars and light-duty (8500 lb. gross vehicle weight or less) trucks equipped with a "low-friction" engine**).**

Field service simulated
Vehicles representative of current production vehicles running under current EPA testing Cycle (FTP) are simulated.

Procedure fixture
A 1993 4.6-liter Ford "modular" V-8 gasoline engine equipped with an external oil heating/cooling system and a "flying flush" system for changing oils without an engine shutdown is used for this procedure.

Procedure parameters
Fuel consumption is measured at each of six speed/load/temperature procedure conditions for an SAE 5W-30 baseline oil (BC). The candidate oil is then introduced and aged for 16 hours. Fuel consumption is measured at each of the six procedure conditions and followed by a repeat of the baseline (BC) oil at the six procedure conditions. Procedure length is 50 hours.

	Stages					
	1	2	3	4	5	6
Speed, rpm	800	800	1500	1500	1500	800
Power, kw	2.18	2.18	5.81	15.39	15.39	2.18
Oil temp, °C	105	70	70	70	45	45
Coolant temp, °C	95	60	60	60	45	45

Procedure parts evaluated
None. Procedure results are expressed as a percent change in kg of fuel consumed for the candidate oil relative to the average of the baseline oil (BC).

Used lubricant analysis
None (new oil viscosity at 40°C and 100°C is required).

Pass/fail criteria
Fuel economy improvement, which equates to the FTP chassis dynamometer procedure, is calculated by
the following formula where units for BSFC are kg/kW-hr:

STAGE (kg/kW-hr)	ACTUAL		NOMINAL POWER (kW)		TIME FACTOR (hr)		FUEL CONS. (kg)
1	BSFC	X	2.18	X	0.077472	=	
2	BSFC	X	2.18	X	0.082500	=	
3	BSFC	X	5.81	X	0.035417	=	
4	BSFC	X	15.39	X	0.078250	=	
5	BSFC	X	15.39	X	0.033139	=	
6	BSFC	X	2.18	X	0.045444	=	
Total mass fuel consumption for all 6 stages = In lieu of original Stage 7 which has been deleted, add 0.2540 kg.							

Compute the total fuel consumed as shown above for the BC oil before the candidate; the candidate oil; and the BC after the candidate.

Calculate the average BC fuel consumption for BC before and after the candidate.

Compute the candidate oil fuel economy improvement (FEI) as follows:

% FEI =
{[BC average – Candidate]/BC average} x 100

Pass/fail criteria for ILSAC GF-2
For SAE viscosity grades:

	Minimum % FEI vs BC
0W-20 and 5W-20	1.4%
Other 0W and 5W multi-viscosity	1.1%
10W multi-viscosity	0.5%

Sequence VIB (ASTM D 6837)

Specifications
API category SL/SM and ILSAC GF-3/GF-4.

Objective
The objective of this procedure is to measure the effects of automotive engine oils on the fuel economy of passenger cars and light-duty (3856 kg, 8500 lb or less gross vehicle weight) trucks equipped with a "low-friction" engine.

Procedure fixture
A 1993 4.6-liter Ford "modular" V-8 gasoline engine equipped with an external oil heating/cooling system and a "flying flush" system for changing oils without an engine shutdown is used for this procedure.

Procedure parameters
Fuel consumption is measured at each of five speed/load/temperature procedure conditions for an SAE 5W-30 baseline oil (BC). The candidate oil is then introduced and aged for 16 hours at Aging Phase I conditions and fuel consumption is then measured for each of the five procedure conditions. The candidate oil remains in the engine and is aged for 80 hours at Aging Phase II conditions. Then fuel consumption is measured for each of the five procedure conditions, followed by a repeat of the baseline (BC) oil at the five procedure conditions.

	AGING STAGES		PROCEDURE STAGES				
	Phase I	Phase II	1	2	3	4	5
Speed, rpm	1500	2250	1500	800	800	1500	1500
Nominal power, kW	15.39	23.10	15.39	2.18	2.18	15.39	15.39
Oil temp, °C	125	135	125	105	70	70	45
Coolant temp, °C	105	105	105	95	60	60	45

Procedure parts evaluated
None; procedure results are expressed as a percent change in kg of fuel consumed for the candidate oil after Aging Phase I and Aging Stage II relative to the baseline oil (BC) before and after candidate oil.

Lubricant analysis
New oil and oil after Aging Phase II viscosity at 40°C and at 100°C is required.

Pass/fail criteria
Fuel economy improvement, which equates to the fuel economy results obtained from vehicles representative of current production vehicles running under the current EPA testing cycles, is calculated by the following formula where units for BSFC are kg/kW-h:

STAGE	ACTUAL (kg/kW-H)	NOMINAL POWER (kW)	TIME FACTOR (h)	FUEL CONS. (kg)
1	BSFC X	15.39	X 0.0802 =	
2	BSFC X	2.18	X 0.0787 =	
3	BSFC X	2.18	X 0.0848 =	
4	BSFC X	15.39	X 0.0864 =	
5	BSFC X	15.39	X 0.0699 =	
Total mass fuel consumption for all 5 stages =				

Compute the total fuel consumed as shown above for the BC oil before candidate; the candidate oil procedure stages after aging phase I; the candidate oil procedure stages after aging phase II; and the BC oil after candidate.

Compute the procedure oil fuel economy improvement (%FEI) as follows:

% FEI Procedure Oil Phase I =
{[(BC before x 80%) + (BC after x 20%) – Procedure Oil Phase I] ÷ [(BC before x 80%) + (BC after x 20%)]}
x 100

% FEI Procedure Oil Phase II =
{[(BC before x 10%) + (BC after x 90%) – Procedure Oil Phase II] ÷ (BC before x 10%) + (BC after x 90%)]}
x 100

Pass/fail criteria for ILSAC GF-3 and API SL
(Minimum %FEI vs ASTM BC)
SAE 0W-20 and 5W-20 viscosity grades:
2.0% minimum after 16 hours aging (Phase I FEI)
1.7% minimum after 96 hours aging (Phase II FEI)

SAE 0W-30 and 5W-30 viscosity grades:
1.6% minimum after 16 hours aging (Phase I FEI)
1.34% minimum after 96 hours aging (Phase II FEI)

All other SAE multi-viscosity grades:
0.9% minimum after 16 hours aging (Phase I FEI)
0.6% minimum after 96 hours aging (Phase II FEI)
1.6% FEI1 + FEI2

Pass/fail criteria for ILSAC GF-4 and API SM
(Minimum %FEI vs ASTM BC)
SAE 0W-20 and 5W-20 viscosity grades:
2.3% minimum after 16 hours aging (Phase I FEI)
2.0% minimum after 96 hours aging (Phase II FEI)
SAE OW-30 and 5W-30 viscosity grades:
1.8% minimum after 16 hours aging (Phase I FEI)
1.5% minimum after 96 hours aging (Phase II FEI)
All other SAE viscosity grades:
1.1% minimum after 16 hours aging (Phase I FEI)

0.8% minimum after 96 hours aging (Phase II FEI)

Sequence VIBSJ

The VIBSJ is an abbreviated length VIB procedure used as a substitution for the Sequence VIA procedure

Specifications
API category SJ and ILSAC GF-2.

Objective
The objective of this procedure is to measure the effects of automotive engine oils on the fuel economy of passenger cars and light-duty (3856 kg, 8500 lb or less gross vehicle weight) trucks equipped with a "low-friction" engine.

Procedure fixture
A 1993 4.6-liter Ford "modular" V-8 gasoline engine equipped with an external oil heating/cooling system and a "flying flush" system for changing oils without an engine shutdown is used for this procedure.

Procedure parameters
Fuel consumption is measured at each of five speed/load/temperature procedure conditions for an SAE 5W-30 baseline oil (BC). The candidate oil is then introduced and aged for 16 hours at Aging Phase I conditions and then fuel consumption is measured for each of the five procedure conditions.

	Aging Stages		Procedure Stages				
	Phase I	Phase II	1	2	3	4	5
Speed, rpm	1500	NR	1500	800	800	1500	1500
Nominal power, kW	15.39	NR	15.39	2.18	2.18	15.39	15.39
Oil temp, °C	125	NR	125	105	70	70	45
Coolant temp, °C	105	NR	105	95	60	60	45

Procedure parts evaluated
None. Procedure results are expressed as a percent change in kg of fuel consumed for the candidate oil after Aging Phase I relative to the baseline oil (BC) before candidate oil.

Lubricant analysis
New oil viscosity at 40°C and at 100C is required.

Pass/fail criteria
Fuel economy improvement, which equates to the fuel economy results obtained from vehicles representative of current production vehicles running under the current EPA testing cycles, is calculated by the following formula where units for BSFC are kg/kW-h:

STAGE	ACTUAL (kg/kW-H)	NOMINAL POWER (kW)		TIME FACTOR (h)		FUEL CONS. (kg)
1	BSFC X	15.39	X	0.0802	=	
2	BSFC X	2.18	X	0.0787	=	
3	BSFC X	2.18	X	0.0848	=	
4	BSFC X	15.39	X	0.0864	=	
5	BSFC X	15.39	X	0.0699	=	

Total mass fuel consumption for all 5 stages =

Compute the total fuel consumed as shown above for the BC oil before candidate; the candidate oil procedure stages after aging phase I.

Compute the procedure oil fuel economy improvement (%FEI) as follows:

% FEI Procedure Oil Phase I =
{(BC before – Procedure Oil Phase) ÷ BC before} x 100

Pass/fail criteria for API SJ and ILSAC GF-2
(Minimum %FEI vs ASTM BC)

SAE 0W-20 and 5W-20 viscosity grades:
2.0% minimum after 16 hours aging (Phase I FEI)

SAE 0W-XX and 5W-XX viscosity grades:
1.6% minimum after 16 hours aging (Phase I FEI)

All 10W- multi-viscosity grades:
0.9% minimum after 16 hours aging (Phase I FEI)

Sequence VIII

Specifications
API SJ, SL, SM

Objective
The objective of this procedure is to evaluate a lubricant's performance in combating copper/lead/tin bearing corrosion and to measure viscous shear stability.

Field service simulated
High-temperature, corrosive service is simulated. Copper/lead/tin bearings. Field service correlation has not been established.

Text fixture
A 42.5 CID carbureted, single-cylinder, spark ignition, CLR oil procedure engine operated with an external oil heater circuit.

Procedure parameters
The engine runs continuously for 40 procedure hours. Procedure speed is 3150 rpm. Oil temperature is raised to 290°F (143°C) using an external oil heater. Unleaded fuel is used.

Procedure parts evaluated
The connecting rod bearing weight loss is measured.

Used lubricant analysis
- Kinematic viscosity
- Multi-grade oils require 10-hour stripped viscosity

Pass/fail criteria
For API SJ, SL, 26.4 weight loss maximum.

Stripped viscosity must stay in grade.

For API SM, 26 weight loss maximum.

Ball Rust Procedure

Specifications
For ILSAC GF-3/GF-4 and API SL, SM.

Objective
The objective of this procedure is to evaluate a crankcase lubricant's performance in combating corrosion of iron engine parts. This procedure replaces the IID Sequence procedure.

Field service simulated
This procedure simulates short trip service under typical winter conditions. It relates most closely to leaded fuel service.

Text fixture
The procedure fixture is a custom-built bench rig centered around a temperature-controlled shaker table. Procedure parts evaluated are specially produced hydraulic lifter check valve balls.

Procedure parameters
Procedures are run for 18 hours. Balls are submerged in the candidate oil and controlled at a temperature of 40°C. During the procedure, an air and acid mix is injected into the oil under controlled flow rates.

Procedure parts evaluated
Post-procedure, the metal balls are removed from the rig, washed per procedure, and rated for surface discoloration using an optical rating/computer/video system. Each candidate oil is typically run in pairs during a single procedure. Up to 5 oils can typically be run at once. A reference oil makes up one or more of those oils.

Used lubricant analysis
None is required.

Pass/fail criteria
Average gray scale value of 100.