

Piston Cleanliness via Fuel Additive Technology

John H. Mengwasser, James Macias, and Edward Nelson
Shell Global Solutions (US) Inc.

ABSTRACT

This work compared the piston deposit ratings in an engine when it was run on gasoline with a high concentration of deposit control additive (DCA) versus gasoline with a low concentration of additive. The additives came from different sources and contained detergents with different functional groups. The engine was a Ford V-8 PFI engine, which is used in ASTM D6593, the Sequence VG test. The experimental procedure followed the ASTM protocol, except for the fuel, which was treated with additives.

Deposit ratings were better, at 95% confidence, in the tests using a high concentration of additive versus the tests using a low concentration.

CITATION: Mengwasser, J., Macias, J., and Nelson, E., "Piston Cleanliness via Fuel Additive Technology," *SAE Int. J. Fuels Lubr.* 6(3):2013, doi:10.4271/2013-24-0101.

INTRODUCTION

Deposits can hinder engine performance as they accumulate on piston components on the oil-side of the engine (piston ring pack and piston skirt) and in the crankcase of SI internal combustion engines [1].

Sludge and varnish are types of deposits. They are made from fuel components when engines work at cool temperatures, such as during stop-and-go driving. The starting materials for these deposits form from the incomplete combustion products of gasoline which enter the crankcase as blow-by. The deposits are created as the gasoline components circulate in the lubricant over the pistons, where they are oxidized and polymerized [2, 3¹]. If they accumulate on the piston skirts as a sticky varnish, solid particles can become imbedded in the varnish, which may cause piston skirt/cylinder bore scuffing [4,5].

Industry standard specifications have been established to ensure lube oils meet performance requirements [6, 7]. North American standards are set by two organizations, the ILSAC and the API (International Lubricant Specification and Approval Committee, American Petroleum Institute).

The current lube oil standards are API SN and ILSAC GF-5. To achieve these standards, an oil must pass several sequence tests, including the Sequence VG. This test is used

to assess lube oil performance at preventing piston deposits and sludge under low temperature conditions.

In previous work, the CRC FL-2 engine test, a predecessor to the VG, was used to show that fuel additives could greatly reduce piston varnish [9]. In this work, we looked to see if modern gasoline additives could reduce piston varnish in the Sequence VG engine test.

EXPERIMENTAL

Test Fluids

The types of fluids (fuel additives and engine oil) used in the experiments reflect what is currently used in the North American market to make the test conditions more similar to field conditions.

Fuels

This program used two fuels for two series of the VG tests: experimental and control. Both fuels were blended from one batch of VG reference fuel to minimize variability. (The fuel spec for the reference fuel is in the [Appendix](#).)

The control series used a blend (LAC fuel) that contained a current, commercially-used additive at a concentration which is the minimum that could be used in gasoline (i.e., the lowest additive concentration or LAC), as certified by the U.S. Environmental Protection Agency (EPA).

¹These reactions are similar to those that occur during oil degradation. The mechanisms are discussed in reference [3].

The experimental series used the same base fuel but was blended with a high-quality additive at a 5 times LAC level concentration. This level is typical of some premium-grade gasolines sold at retail stations in North America.

In addition to different concentrations, the additives came from different sources and contained detergents with different functional groups.

Motor Oil

A single batch of commercially-available SAE 5W-30 motor oil (GF5/SN) was used to supply lubricant for all tests in the program. The finished oil formulation contained a mixture of Group II and III base oils and all of the additives typically found in engine oil meeting the current ILSAC GF-5/API SN specifications.

Sequence VG Engine Tests

The Sequence VG test evaluates the lube oil performance in preventing sludge and varnish formation under low-temperature conditions, e.g., such as those found in stop-and-go driving cycles. The test uses a Ford 4.6 L V8 gasoline engine and is run for 216 hours, consisting of 54 cycles of 4 hours each. Each cycle consists of three stages set at the conditions shown in Table 1 [9]. Unleaded Haltermann SVGM2 fuel is used, and the engine blow-by is intentionally increased to shorten the test duration.

Table 1. Sequence VG Test Conditions

	Stage 1	Stage 2	Stage 3
Time (min)	120	75	45
Speed (rpm)	1200	2900	700
Load (kPa)	69	66	Record
Oil T (°C)	68	100	45
Coolant T (°C)	57	85	45
Rocker Cover T (°C)	29	85	29

Performance in this test is based on a rating system in which deposits on select engine parts are evaluated on a scale of 1 to 10; 10 for a perfectly clean part and one for an excessively dirty part. The parts rated are: rocker arm cover (2), valve deck (2), camshaft baffle (2), timing chain cover, oil pan, oil pan baffle, piston skirts (8, thrust side only), and left and right camshaft baffles. Although all measurements from the test were pertinent to this investigation, the single inspection item that seemed most likely to be affected by fuel additive technology was the average piston skirt varnish (APSV) rating, based on reference 8. The rated parameters and pass/fail limits for GF-5 quality oils are shown in Table 2.

Table 2. Minimum Pass / Fail Limits of VG Rated Parameters for GF-5 Quality Oil

Parameter	Pass Limit
AES ²	8.0 merits
RCS ³	8.3 merits
AEV ⁴	8.9 merits
APSV ⁵	7.5 merits

All Sequence VG tests were performed according to ASTM D6593, the official Sequence VG test protocol, except for the fuels, which were treated with additives. To minimize variability, the tests were performed in a single, newly referenced engine stand. The test matrix is shown in Table 3.

Table 3. Test Matrix

Test Number	Fuel	Lube Oil
1	Ctrl	GF5/SN
2	Exp	GF5/SN
3	Ctrl	GF5/SN
4	Exp	GF5/SN
5	Ctrl	GF5/SN
6	Exp	GF5/SN

RESULTS AND DISCUSSION

Figure 1 shows the average ratings from the three tests in each series. The figure shows that the series using Exp fuel had better ratings for all of the parameters. As anticipated, the APSV rating was the inspection item most affected by fuel additive technology.

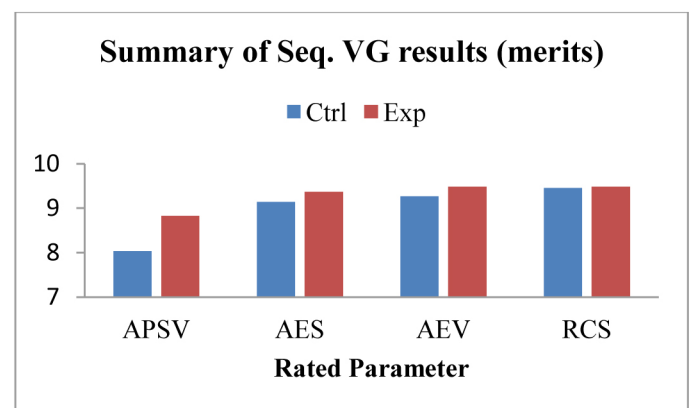


Figure 1. Summary of Sequence VG results for all of the rated parameters. Each rating is the average of three tests.

² AES: average engine sludge

³ RCS: rocker cover sludge

⁴ AEV: average engine varnish

⁵ APSV: average piston skirt varnish