

## PERFORMANCE TESTS

# Introduction

We will continue to keep you informed on the development of performance tests by the various ASTM Surveillance Panels, including details relating to the purpose, running conditions and status.

See the following pages for specifics on the various performance tests:

### Tests Under Development:

Sequence IIIG	D-3
<b>Sequence III GA</b>	<b>D-4A8</b>
Sequence VIC (Modified VIB)	D-5
Sequence VII (OPEST)	D-7

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12/03

### Existing Tests:

BRT (ASTM D 6557)	D-9
Sequence VG (ASTM 6593)	D-10
Sequence IVA	D-11
Sequence VIII	D-12
MHT-4 TEOST	D-13

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# Proposed Performance Tests

The following performance tests are currently being considered by ILSAC for inclusion in the GF-4 category.

Performance Characteristic	Proposed Test
Engine Rusting	Ball Rust Test (BRT)
Viscosity Control	Sequence IIIG
Low Temperature Sludge	Sequence VG
Low Temperature Wear	Sequence IVA
High Temperature Wear	Sequence IIIG
Fuel Economy Improvement	<b>Sequence VIC (Modified VIB) <sup>(1)</sup></b>
High Temperature Deposits	Sequence IIIG and MHT #4 TEOST
Bearing Corrosion	Sequence VIII
Catalyst Compatibility	0.05% phosphorus max. or Sequence VII
Low Temperature Viscosity	Sequence IIIG
Shear Stability	Sequence VIII
Oil Consumption	NOACK and GCD distillation
Foaming/Oil Aeration	ASTM D892/ASTM 6082
Filterability	EOFT and EOWTT

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Details on test status follow.

- (1) At the September 2002 ILSAC/Oil meeting, ILSAC announced that VIC development work was terminated for GF-4, and the standard VIB with new performance limits will be used for GF-4.

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## PERFORMANCE TESTS

# Sequence IIIG

### SCOPE:

The Sequence IIIG is a replacement for the Sequence IIIF but is expected to use the same basic engine hardware as the IIIF. Test operating conditions and special test hardware modifications are under evaluation by General Motors. The IIIG test development objectives are:

- Increase oxidation severity to 2xIIIF level
- Improve wear discrimination relative to IIIF
- Directionally increase piston deposit severity relative to IIIF

### Rated parameters:

- **High temperature viscosity increase (KV@40C)**
- **Weighted Piston Deposits (WPD)**
- **Average Cam Wear & Lifter Wear (AC&LW)**
- **Hot Stuck Piston Rings**

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IIIG test development started in June 2001 and was expected to be complete by early 2002. Timing for completion of test development (**IIIG ready for precision matrix**) is now estimated as **February 2003**.

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As with the IIIF, special camshaft surface finishing (slightly rougher than production) is used to increase wear. The IIIG cams are lightly phosphated to prevent scuffing during engine break-in. During evaluation of the phosphating process, it was found that phosphate thickness significantly affects cam wear performance. The initial cams, 'MKP' used from May to October 2002, had a phosphate thickness of about 2 micrometers. This was increased to about 10 micrometers with the 'NF200' cams, which were introduced in mid-November 2002. Engine operation is at high speed and temperature to increase oxidation.

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The Sequence IIIG procedure is designed to evaluate an oil's resistance to oxidation and wear in high speed and high temperature vehicle operation.

## PERFORMANCE TESTS

# Sequence IIIG

### TEST CONDITIONS:

	<u>IIIF</u>	<u>IIIG*</u>
Engine:	GM 3.8L V-6 (3800cc)	GM 3.8L V-6 (3800cc)
Engine Speed (RPM):	3600	3600
Engine load (Nm):	200	250
Oil temperature (°C):	155	150
Coolant temperature (°C):	122	115
Intake air (°C):	27	35
Valve Spring Load (lbs)	180 @ 0.375 inch deflection	205 @ 0.375 inch deflection
Test Length (hours):	80	100?
Fuel:	Haltermann fuel unleaded (Dyed red)	Haltermann fuel unleaded
Air/Fuel Ratio	15:1	15:1
Piston Ring Gap		
Top Ring (IN)	0.042	0.025
2nd Ring (IN)	0.038	0.042
Initial Oil Charge (ml)	5500	5500
Oil Checks (hr)	10	20
Cam Bushings Material	Babbitt	Babbitt
Lifter Material	ACI	ACI (same as IIIF)
<b>Cam Shaft</b>		<b>Phosphated IIIF</b>
Cam Thrust Plate (IN)	0.1530	0.1530

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\* Current IIIG development test conditions and hardware subject to possible change with further development activity. **The camshaft phosphating process was significantly modified in November 2002.**

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12/02

### KEY CURRENT ACTIVITIES:

- GM is conducting IIIG test development runs at the two San Antonio independent test laboratories – SouthWest Research Institute and Perkin-Elmer.
- IIIG development evaluation runs began in June 2001.

During the ASTM Sequence IIIF Surveillance panel meeting held in San Antonio on November 15, 2001, General Motors presented their first industry update on IIIG development

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**December 2002**

activity. They updated it at the December 5, 2001 ASTM Tech B meeting (see pages D-4B – D-4F). A total of 12 tests had been completed at that time. After the first eight tests were complete, the test procedure was modified to use directionally stiffer valve springs 205# versus earlier 180# @ 0.375 inches of deflection. This was done to increase wear severity since a modified GF-3 quality oil (phosphorus reduced from 0.095% down to 0.05%) gave low wear with the original IIIF valve spring pressures. GMs intent is that oils with reduced phosphorus to this level should fail wear if no auxiliary antiwear component is added to counter the loss in wear protection from the removal of ZDDP. When the valve spring pressure was increased to 205# this 0.05% phosphorus reference oil did give poor wear while the fully formulated GF-3 oil produced good wear. GM are now concentrating on deposit and oxidation performance. Test length may eventually be increased beyond the current 100-hour duration to get desired oxidation severity. The target performance is about double length IIIF level.

General Motors now are targeting to have the IIIG procedure ready for release to industry by end of 1Q 2002.

Sequence IIIG development tests have experienced valve train break-in wear scuffing variability resulting in high cam lobe wear. Work during the early part of 2002 has been focused on resolving this condition. Several approaches have been investigated:

- 1.) Prelube cam with GM Engine Oil Supplement
- 2.) Camshaft oiling bar
- 3.) Super Proferall 55 cam
- 4.) Camshaft oiling bar and Super Proferall 55 cam
- 5.) Phosphated cam

IIIG development is delayed due to this valve train break-in wear (scuffing) evaluation activity. General Motors now estimates that IIIG procedure development will be complete by July 1, 2002 and precision matrix testing will be complete by September 2002.

**GM updated industry on IIIG development status at the May 16, 2002 Sequence III Surveillance panel meeting held in Detroit. After investigating numerous approaches to prevent**

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June 2002

cam/lifter scuffing wear during initial engine start-up, GM reported they are using IIF cams but adding a light manganese phosphate coating of about 2 microns. These are designated as "MKP" cams or IIF cams that were phosphated. Several phosphate batches of "MKP" cams were made from May to August 2002 and used widely by industry for GF-4 candidate oil technology development. A test results summary for the **early** IIG development tests conducted to date by GM is tabulated on page D-4E. A summary of development tests with the finalized test conditions (using "MKP" phosphated cams) is included on page D-4E-1.

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At the May 16 meeting GM reported they had completed IIG test development and were now releasing the test and hardware to industry for candidate oil evaluation testing. GM stated their goal of 2x IIF oxidation had not quite been realized but weighted piston deposit (WPD) severity has been significantly increased. In order to keep a reasonable performance balance of these two parameters, GM recommended that test length remain at 100 hours. The Surveillance panel accepted GMs report and actions.

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8/02

ASTM has formed a GF-4 matrix Task Force to design and implement a IIG matrix by year-end 2002. Current schedule timing is for the IIG matrix to start by November 1 and complete by year-end 2002.

GMs IIG development effort included investigation of changes in the Weighted Piston Deposit (WPD) rating method (new rated areas and revised area weighting factors) to better discriminate oil quality. However, on July 22, 2002 GM formally announced that this work was complete and after careful review of the data, GM decided to continue using the IIF WPD rating technique for the IIG.

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IIG performance pass/fail limits for GF-4 have not yet been established but GM presented the following pass/fail limits proposal at the August 6, 2002 ILSAC/Oil meeting:

- Viscosity increase, maximum: (150%)
- Weighted Piston Deposits, minimum: (4.0 merits)
- Piston Skirt Varnish merits, minimum: (9.0 merits)
- Avg. Cam and Lifter Wear, Maximum: (30 micrometers)
- Low temperature used oil viscosity: (maximum of one SAE viscosity grade increase)

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As of the August 6, 2002 ILSAC/Oil meeting, GM has not presented data on any GF-4 prototype oil that meets their proposed minimum IIIG performance requirements proposal. Thus, continued industry debate about the appropriate level for each of these limits is expected.

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During the November 20, 2002 ASTM Sequence IIIG surveillance panel meeting held in San Antonio, it was reported that in late August 2002 the cam supplier determined the "MKP" cam phosphating had been conducted at too low a temperature (about 160° F), resulting in insufficient phosphate coating. 'Rust blush' was observed on the lobes of some cams. The cam supplier initiated a phosphating process change to improve production quality and reproducibility. Cams were processed at a bath temperature of 190° F. Sequence IIIG testing of this material with known reference oils indicated valvetrain wear was dramatically increased so these cams were not released for candidate oil evaluation. The cam supplier and GM focused intensive research on the camshaft phosphating process in an effort to repeatedly manufacture cams with wear performance similar to that experienced with "MKP" material. GM and the cam supplier reported their status at the ASTM IIIF surveillance panel meeting held on November 20, 2002. The phosphating process has been further modified and documented, but details are proprietary to the supplier (OHT) and GM. The manufacturing has been moved to a new source and bath temperature raised to 200°F. GM stated that this phosphating process will be used for all future IIIG cam production. Cams made to date with this process have been identified as "NF200". Sequence IIIG cams will no longer be produced in large batches but rather made on an as-needed basis. The cam supplier stated this is possible since the manufacturing process is now tightly defined and controlled. Reference oil test data on the "NF200" cams were presented to demonstrate the wear performance relative to "MKP" experience. GM is running a few additional tests to further demonstrate the "NF200" cam performance and phosphate process repeatability. The summary data for development tests with "NF200" cams are included on page D-4E-2.

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**The ASTM IIIG surveillance panel met in San Antonio on February 19 to discuss readiness of the IIIG procedure for precision matrix testing. Two significant concerns were raised and debated extensively:**

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**Wear and deposit severity difference between labs**

Test data conducted since the February 19 meeting were judged to indicate that the wear bias between PE and SwRI has been corrected. Dual lab ratings will be performed on the matrix tests to determine rater variability and bias. A rating workshop will be conducted to better align rater techniques.

**Oil filter plugging / used oil contamination**

The root cause for the random instances of filter plugging experienced during IIIG development testing is unknown. Bench filter flow testing with fresh oil samples confirms normal, low filter delta pressure. Relatively high levels (up to 100 ppm) of Na have been observed in EOT oil samples of some IIIG tests; this is suspected of being a contributor to filter plugging. The Na appears to be a carryover from the engine block washing process, which will be reviewed and enhanced as necessary prior to matrix testing.

**Critical test parts tracking and batch information reporting**

A process for identifying and reporting the manufacturing batch information of all 'critical' engine parts was agreed. All critical parts will be used on a 'first in / first out basis'.

**Method for collecting EOT oil samples and measuring CCS and MRV performance**

There is concern that measured results may deteriorate if analytical tests are not conducted in a very timely manner after engine test completion. MRV performance versus sample storage time at 75°F will be examined for the precision matrix tests. CCS will be measured four hours after engine EOT. MRV will be run both four hours after CCS determination and 168 hours after test EOT.

The vote for the recommendation to the PCEOCP that the IIIG precision matrix is ready to begin was 11 for, 0 opposed, 3 waive. The matrix is expected to start by May 1 and complete by the end of May. The next Sequence III surveillance panel is tentatively scheduled for June 10 to review the precision matrix results analysis report.

The Sequence IIIG precision matrix was started on May 1 and is expected to be complete by early June. The matrix is being conducted at PE and SwRI utilizing three test stands at each laboratory. The ASTM TMC administrator John Zalar is also the IIIG matrix program test manager. John is issuing and posting regular data updates on the ASTM Web page as it is reported to the TMC. ([ftp.astmtmc.cmu.edu/docs/gas/GF-4\\_matrix](ftp.astmtmc.cmu.edu/docs/gas/GF-4_matrix))

A summary of the data is also included here on page D-4G. The next Sequence III surveillance panel meeting is tentatively scheduled for June 10, 2003.

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5/03

**The Sequence IIIF/IIIG surveillance panel met in Detroit on June 10, 2003 to review the IIIG precision matrix test results and the statistical teams' analyses. There was lengthy discussion of the data as precision of most parameters was poorer than desired by ACC. Ultimately the group approved the following motion with a vote of 9 for, 0 against, 2 waive. "Recommend to the PCEOCP that the Sequence IIIG test be considered for inclusion in the GF-4 specification based on matrix data". This recommendation was unanimously endorsed by the PCEOCP at their meeting of June 17. The IIIF/IIIG surveillance panel requested the statistical group to pursue further matrix data analysis to better understand laboratory differences in oil consumption and WPD performance, correlations between KV40 and MRV, influence of oil consumption, NOx and blowby on rated parameters. This additional analysis is expected to be complete by June 30.**

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12/03

**The Sequence IIIG panel held a telephone conference on August 1, 2003 to discuss a recently discovered variation in second ring face roughness that appears to have an impact oil consumption. The critical parts supplier (OHTechnologies) with the support of GM recommended that all current supplies of second piston rings be recalled and sorted by face roughness, and that only those in the lower one third of the current roughness specification be used. Secondly, they recommended that a new batch of rings be produced immediately with a new roughness specification to reflect the smoother face surface desired. These recommendations were endorsed by the IIIG surveillance panel. A review of the IIIG matrix data indicates that rings with a face finish on the**

smoother side of the original specification tend to give directionally lower oil consumption. It was agreed that all future IIG tests will use the new smoother specification second ring, and OHT plans to have hardware available by August 7.

The Sequence IIG panel meet on October 29 in San Antonio, Texas, to conduct semi-annual business. The issue of IIG oil consumption variability was discussed at length, and Perkin Elmer reported that they now had reduced oil consumption via a revised honing technique. The group considered the honing technique to be within test procedure guidelines. The group requested the honing task force to continue work on establishing a proposal for a standardized engine block honing technique so that laboratory reproducibility of oil consumption could be further improved. The statistical work group had met via telephone conference on October 15 and concluded that a statistically based severity adjustment of viscosity results for oil consumption variability would not be needed due to the use of smooth rings and recent honing refinements. The statistical group did, however, recommend to the IIG surveillance panel that the following actions be considered:

1. Adopt a standardized block honing and cleaning process. Report the bore finish in each test report.
2. Confirm that the oil consumption performance of smooth rings for engine bore sizes 1 thru 4 is equivalent to that experienced with bore sizes 5 and 6.
3. Develop an operationally invalid limit on oil consumption for early test hours to eliminate unacceptable engine builds.
4. Develop a non-interpretible definition for tests that experience end of test oil consumption above a defined high limit.

The IIG surveillance panel agreed to complete items one and two before year end 2003 and items four and five were added to the group's objectives.

The IIIG panel reviewed a request from ACC that a separate test procedure 'IIIGA' be established for evaluation of MRV performance and that MRV performance be removed from the standard IIIG procedure. This action was taken.

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12/03

The Sequence IIIG surveillance panel held a telephone conference on December 15 to receive the honing task force report and take appropriate action. The main recommended update to the honing process was a requirement to have the laboratory honing machine's load setting calibrated by the machine manufacturer. This was agreed and most laboratories have had this done recently. The following motion was approved:

**'Implement the honing task force recommendation with an operationally valid calibration test. All tests thereafter must use the new honing process. The effective date is December 15 and must be implemented within 100 days. Notation of the honing procedure change must be noted in the first calibration test report.'**

## PERFORMANCE TESTS

# Sequence IIIGA

### SCOPE:

The Sequence IIIGA is the same procedure as the Sequence IIIG but is used only to measure low temperature used oil viscosity (MRV) performance. Test operating conditions and special test hardware modifications are the same as for the IIIG test.

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### Rated Parameter:

- Low Temperature Viscosity (MRV)

The Sequence IIIGA test is separate from the IIIG and thus both are treated as individual procedures by ILSAC, ASTM and API. The ACC code of practice rules are applied separately to each of the IIIG and IIIGA tests. This means that repeat testing can be run with the IIIG and/or IIIGA as required for Multiple Test Acceptance (MTAC) and minor formulation modification of each test type. MTAC does not apply to used oil pumpability measured by the MRV-TP1 test.

## Sequence IIIG Development Data

Lab/Run #	Viscosity	Test Oil	Spring Load	Cam ID	Oil Bar	Fe @ Initial	% Vis. Inc.	Avg. Wear	WPD	PSV	Oil Cons.
SR/01	5W-30	433-1	180	MB	No	21	6467	132	2.21	7.87	4.43
SR/02	5W-30	433-1	180	MB	No	4	287	28	2.62	7.96	3.85
PE/01	5W-30	433-1	180	MB	No	5	130	37	2.82	8.32	4.09
SR/03	5W-30	403 Reformulated	180	MB	No	4	TVTM	14	1.6	8.2	TVTM
SR/04	5W-30	1006 Reformulated	180	MB	No	6	1077	27	2.36	8.62	3.61 @ 80h
SR/05	5W-30	0.03 Phos.	180	MB	No	17	105	105	3.92	8.4	3.74
SR/06	5W-30	0.03 Phos.	180	MB	No	16	156	267	2.85	7.79	3.7
PE/02	5W-30	0.05 Phos.	180	MB	No	3	130	26	3.16	8.69	3.78
PE/03	5W-30	0.05 Phos.	205	MB	No	19	133	153	3.32	8.52	3.99
PE/04	5W-30	0.095 Phos	205	MB	No	4	176	16	3.23	8.84	4.55
SR/07	0W-30	GM-1	205	MB	No	5	106	57	4.64	9.17	2.71
PE/05	5W-20	Prototype GF-4	205	MB	No	5	110	53	2.64	7.52	4.47 @ 77.8h
PE/06	5W-20	GF-3	205	MB	No	29	149	337	2.16	7.18	4.66 @ 76.8h
SR/08	5W-20	GF-3	205	MB	No	42	587	270	2.52	7.53	4.63
PE/07	5W-30	0.03 Phos.	205	MB	No	1	5601	483	2.52	8.76	4.98
SR/09	5W-30	0.03 Phos.	205	MK	Yes	4	293	49.6	3.27	8.48	4.12
SR/10	5W-30	0.095 Phos.	205	MK	Yes	5	173	11.7	3.3	8.8	4.3
SR/11	5W-20	Prototype GF-4	205	MK	Yes	N/A	N/A	N/A	N/A	N/A	N/A
PE/08	5W-30	0.03 Phos.	205	MK/P	No	9	170	51.3	3.53	9.07	3.78
SR/12	5W-20	Prototype GF-4	205	Pro 55	Yes	17	92	71	2.74	7.27	3.92
PE/09	5W-20	Prototype GF-4	205	MK/P	No	9	102	57.2	2.53	7.74	3.78
SR/13	5W-20	Prototype GF-4	205	MK/P	No	9	88	38.5	2.79	7.94	3.95
PE/10	5W-30	0.095 Phos.	205	MK/P	No	6	166	17.6	3.35	9.45	3.35
PE/11	10W-30	GF-3	205	MK/P	No	10	175	17.6	3.24	8.21	3.4
SR/14	5W-20	Reference 538	205	MK/P	No	9	118	12.8	3.5	9.16	4.2
SR/15	5W-30	0.05 Phos.	205	MK/P	No	9	107	17.7	3.30	9.26	3.32
SR/16	15W40	0.12 Phos. Gpl	205	MK/P	No	8	6831	66.8	3.97	8.89	2.79
SR/17	15W40	0.12 Phos. Gpll	205	MK/P	No	6	1657	16.1	5.36	9.56	3.95
PE/12	5W20	Reference 538.	205	MK/P	No	7	117	14.2	3.70	8.93	3.86
SR/18	5W30	433-1	205	MK/P	No	8	150	62.0	2.37	7.19	3.51

**Final Proposed Test Procedure**

**Sequence IIIG Tests with “MKP” Phosphated Camshafts**

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12/02

Lab/Run #	Viscosity Test	Test Oil	% Vis. Inc.	Avg. Wear	WPD	PSV	Oil Cons.
PE/08	5W-30	0.03 Phos.	170	51.3	3.53	9.07	3.78
PE/09	5W-20	Prototype GF-4	102	57.2	2.53	7.74	3.78
PE/10	5W-30	0.095 Phos.	166	17.6	3.35	9.45	6.09
PE/11	10W-30	GF-3	175	17.6	3.24	8.21	3.4
SR/13	5W-20	Prototype GF-4	88	38.5	2.79	7.94	3.95
SR/14	5W-20	GF-3 TMC Ref. 538	118	12.8	3.5	9.16	4.2
SR/15	5W-30	0.05 Phos.	107	17.7	3.30	9.26	3.32
SR/16	15W-40	0.12 Phos. Gpl	6831	66.8	3.97	8.89	2.79
SR/17	15W-40	0.12 Phos. Gpll	1657	16.1	5.36	9.56	3.95
PE/12	5W-20	GF-3 TMC Ref. 538	117	14.2	3.70	8.93	3.86
SR/18	5W-30	TMC Ref. 433-1	150	62.0	2.37	7.19	3.51
<b>PE/13</b>	<b>5W-30</b>	<b>TMC Ref. 433-1</b>	<b>228</b>	<b>35.9</b>	<b>2.76</b>	<b>8.52</b>	<b>4.36</b>
<b>PE/14</b>	<b>5W-20</b>	<b>Prototype GF-4 (A)</b>	<b>327</b>	<b>34.8</b>	<b>3.73</b>	<b>9.01</b>	<b>4.33</b>
<b>PE/15</b>	<b>5W-20</b>	<b>Prototype GF-4 (A)</b>	<b>312</b>	<b>32.6</b>	<b>4.29</b>	<b>9.23</b>	<b>4.67</b>
<b>SR/xx</b>	<b>5W-20</b>	<b>Prototype GF-4 (A)</b>	<b>132</b>	<b>31.7</b>	<b>4.43</b>	<b>8.92</b>	<b>N/A</b>

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12/02

D-4E-1

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**Final Proposed Test Procedure**

**Sequence IIIG Tests with “NF200” Phosphated Camshafts**

Lab/Run #	Viscosity Test	Test Oil	% Vis. Inc.	Avg. Wear	WPD	PSV	Oil Cons.	MRV @ -30
<b>PE/OHT</b>	5W-30	TMC Ref. 433-1	191	37.7	2.94	8.46	4.09	<b>&gt;400,000</b>
SR/OHT	5W-20	GF-3 TMC Ref. 538	91.6	17.9	2.9	8.73	3.80	<b>18,100</b>
PE/16	5W-20	GF-3 TMC Ref. 538	118.9	16.8	3.3	9.04	4.61	<b>22,800</b>
SR/19	5W-30	TMC Ref. 433-1	TVTM	98.9	3.13	8.51	4.31	<b>N/A</b>
PE/17	5W-20	GF-3 TMC Ref. 538	101.2	15.8	2.64	8.10	3.29	<b>20,300</b>
SR/20	5W-20	GF-3 TMC Ref. 538	92.7	19.3	2.89	8.25	3.12	<b>17,500</b>
PE/18	5W-30	0.03 Phos.	114	36.7	3.24	8.48	3.66	<b>57,400</b>
SR/21	5W-20	Candidate Ref Oil A	106	44.6	3.74	8.46	3.50	<b>28,100</b>
PE/19	5W-30	Candidate Ref Oil B	91	21.0	4.21	8.70	3.67	<b>26,300</b>
<b>PE/20</b>	<b>5W-30</b>	<b>TMC Ref. 433-1</b>	<b>153</b>	<b>37.8</b>	<b>3.14</b>	<b>8.64</b>	<b>4.13</b>	<b>&gt;400,000</b>
SR/22	5W-30	Candidate Ref Oil B	155	42.2	4.06	8.66	3.44	<b>108,600</b>
SR/23	5W-20	Candidate Ref Oil C	159	43.2	2.97	7.88	3.73	<b>70,700</b>
PE/	5W-20	Candidate Ref Oil C	228	32.8	3.19	8.96	<b>4.30</b>	<b>266,630</b>
LZ	5W-20	GF-3 TMC Ref. 538	159	29.9	3.73	8.76	NA	
LZ	5W-20	GF-3 TMC Ref. 538	117	35.6	2.85	8.46	NA	

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**4/03**

**D-4E-2**

**April 2003**

## Final Proposed Test Procedure Continued

### Sequence IIIG Tests with "NF200" Phosphated Camshafts

Lab/Run #	Viscosity Test	Test Oil	% Vis. Inc.	Avg. Wear	WPD	PSV	Oil Cons.	MRV @ -30
PE/21	5W-20	Candidate Ref Oil C	166	45	3.40	8.38	3.88	81,700
SR/24	5W-20	Candidate Ref Oil C	133	41.2	3.0	8.31	3.54	49,600
SR/25	5W-30	Candidate Ref Oil B	TVTM	56.1	2.82	8.62	4.19*	N/A
PE/22	5W-30	Candidate Ref Oil B	148	38.4	4.37	9.20	4.64	61,400
SR/25A	5W-30	Candidate Ref Oil B	157	41.8	3.67	8.8	3.89	92,700
SR/26	5W20	GM-2	168	69.9	2.84	7.60	3.64	41,100
PE/23	5W-20	GM-2	146	80.0	3.29	8.59	3.57	38,600

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4/03

\* Oil consumption at 80 hours

D-4E-3

April 2003

# Sequence IIIG

- 3800 Series II (Current production scheduled through 2009)
  - Same test components as Sequence IIIF
  - Modifications to IIIF to enhance severity
    - Test length 100h vs 80h
    - 20h levels vs 10h (5500 ml initial with 472 ml additions)
    - Inlet air temp 35°C vs 27°C
    - 250 Nm vs 200 Nm @ 3600 RPM
  - Modifications to reduce oil consumption
    - Rings .025 Top / .042 2<sup>nd</sup> vs .042 / .038
    - Coolant temp 115°C vs 122°C
    - Oil temp 150°C vs 155°C

D-4B

# Sequence IIIG

- Operating Conditions
  - 5500ml initial oil charge
  - 100 hour test length
  - 20 hour levels with 472 ml new oil additions
  - 15:1 Air-to-Fuel
  - 3600 RPM @ 250 Nm Load
  - 115°C Coolant
  - 150°C Oil
  - 35°C Inlet Air

D-4C

# Sequence III G

- 12 runs to date
- Oils
  - 433-1
  - 1006 Reformulated
  - 403 Reformulated
  - 0.03 Phos
  - 0.05 Phos.
  - 0.10 Phos.
  - GF-4 Prototype
  - GM-1

D-41D

# Sequence III G

## Quick Summary

DAE

Lab/Run#	Viscosity	Test Oil	% Vis. Inc.	Avg. Wear	WPD	PSV	Oil Cons.	Comments:
SR/01	5W-30	433-1	6467	132	2.21	7.87	4.43	High B/B .042/.038 ring gap EF-411 build 180lb. Springs
SR/02	5W-30	433-1	287	28	2.62	7.96	3.85	.025/.042 ring gap - Test oil build - 180lb. springs
PE/01	5W-30	433-1	130	37	2.82	8.32	4.09	.025/.042 ring gap - Test oil build - 180lb. springs
SR/03	5W-30	403 Reformulated	TVTM	14	1.6	8.2	TVTM	.025/.042 ring gap - Test oil build - 180lb. springs
SR/04	5W-30	1006 Reformulated	1077	27	2.36	8.62	3.61	.025/.042 ring gap - Test oil build - 180lb. springs
SR/05	5W-30	0.03 Phos.	105	105	3.92	8.4	3.74	.025/.042 ring gap - Test oil build - 180lb. springs
SR/06	5W-30	0.03 Phos.	156	267	2.85	7.79	3.7	.025/.042 ring gap - Test oil build - 180lb. springs
PE/02	5W-30	0.05 Phos.	130	26	3.16	8.69	4.25	.025/.042 ring gap - Test oil build - 180lb. springs
PE/03	5W-30	0.05 Phos.	133	153	3.32	8.52	3.99	.025/.042 ring gap - Test oil build - 205lb. springs
PE/04	5W-30	0.095 Phos.	176	16	3.23	8.84	5.1	.025/.042 ring gap - Test oil build - 205lb. springs
SR/07	0W-30	GM-1	106	57	4.64	9.17	2.71	.025/.042 ring gap - Test oil build - 205lb. springs
PE/05	5W-20	Proto-type GF-4	110	53	2.64	7.52	4.47 @ 77.8h	EOT @ 77.8 h. Low Oil Level / Lifter Collapse

Blue denotes initial run with reverse gap strategy and EF-411 build

Standard test conditions:	0.025 / 0.042 Ring gap
5500 ML Initial oil fill	150°C Oil temperature
15:1 Air-to-Fuel Ratio	250 Nm Torque
20 Hour oil levels	High tension oil rails
35°C Intake air	Engine build with test oil



# Sequence IIIG

## Next Steps

Current plans:

- Run additional “selected” commercial oils to further enhance pass/fail discrimination
- Look closer at deposit ratings
  - Remove PSV from WPD
  - Add top land rating to WPD
- Determine test length
- Release target of 4/02

D-4F



## Sequence IIIG Precision Matrix Tests

Lab/Stand	Viscosity Test	Test Oil	Cam Batch	% Vis. Inc.	Avg. Wear	WPD	PSV	Oil Cons.	Stuck Rings	MRV @ -30
B/5	5W-30	434	1	133.3	41.1	3.15	8.61	3.86	0	<b>48,900</b>
A/1	5W-30	434	1	89.9	26.2	5.83	9.43	3.98	0	31,900
B/4	5W-30	434	2	127.5	43.7	3.39	8.81	4.23	0	<b>49,200</b>
<b>A/1</b>	5W-30	434	<b>2</b>	<b>249.5</b>	<b>37.1</b>	<b>4.77</b>	<b>8.74</b>	<b>4.65</b>	<b>0</b>	<b>86,400</b>
<b>B/4</b>	5W-30	434	<b>1</b>	<b>99.2</b>	<b>33.1</b>	<b>4.32</b>	<b>8.76</b>	<b>3.90</b>	<b>0</b>	<b>45,600</b>
<b>A/3</b>	5W-30	434	<b>1</b>	<b>86.7</b>	<b>39.1</b>	<b>4.42</b>	<b>8.83</b>	<b>3.47</b>	<b>0</b>	<b>34,200</b>
<b>B/6</b>	5W-30	434	<b>2</b>	<b>185.7</b>	<b>40.2</b>	<b>3.83</b>	<b>8.36</b>	<b>4.39</b>	<b>0</b>	<b>108,900</b>
<b>A/2</b>	5W-30	434	<b>2</b>	<b>62.8</b>	<b>34.2</b>	<b>4.99</b>	<b>9.04</b>	<b>3.71</b>	<b>0</b>	<b>29,000</b>
A/2	5W-20	435	2	172.2	45.8	3.26	8.84	3.74	0	84,500
B/4	5W-20	435	2	163.4	30.9	2.90	8.57	3.86	0	84,800
A/3	5W-20	435	2	222.2	31.6	3.31	7.98	4.22	0	<b>300,200</b>
B/5	5W-20	435	1	279.0	26.8	3.30	8.76	4.3	0	<b>210,700</b>
<b>B/6</b>	5W-20	435	<b>1</b>	<b>304.8</b>	<b>48.7</b>	<b>4.12</b>	<b>8.11</b>	<b>4.31</b>	<b>0</b>	<b>400,000</b>
<b>A/2</b>	5W-20	435	<b>1</b>	<b>176.4</b>	<b>33.0</b>	<b>3.92</b>	<b>8.32</b>	<b>4.25</b>	<b>0</b>	<b>91,900</b>
<b>B/5</b>	5W-20	435	<b>2</b>	<b>230.2</b>	<b>34.6</b>	<b>2.97</b>	<b>8.63</b>	<b>4.21</b>	<b>0</b>	<b>294,000</b>
<b>A/1</b>	5W-20	435	<b>1</b>	<b>167.7</b>	<b>46.8</b>	<b>3.28</b>	<b>8.36</b>	<b>3.79</b>	<b>0</b>	<b>110,100</b>
A/3	5W-20	438	2	102.3	14.4	3.04	8.96	3.62	0	<b>19,300</b>
B/6	5W-20	438	2	132.6	16.8	3.68	9.39	4.27	0	23,700
A/2	5W-20	438	1	111.7	21.2	3.14	8.86	3.47	0	<b>20,500</b>
<b>B/6</b>	5W-20	438	<b>1</b>	<b>143.2</b>	<b>15.3</b>	<b>2.85</b>	<b>8.91</b>	<b>4.33</b>	<b>0</b>	<b>30,400</b>
<b>B/5</b>	5W-20	438	<b>2</b>	<b>120.6</b>	<b>20.8</b>	<b>3.00</b>	<b>8.26</b>	<b>3.87</b>	<b>0</b>	<b>20,800</b>
<b>B/4</b>	5W-20	438	<b>1</b>	<b>91.7</b>	<b>15.6</b>	<b>4.17</b>	<b>8.65</b>	<b>3.41</b>	<b>0</b>	<b>19,000</b>
<b>A/1</b>	5W-20	438	<b>2</b>	<b>88.6</b>	<b>22.0</b>	<b>3.08</b>	<b>9.20</b>	<b>3.32</b>	<b>0</b>	<b>16,700</b>
<b>A/3</b>	5W-20	438	<b>1</b>	<b>90.5</b>	<b>21.4</b>	<b>3.26</b>	<b>8.82</b>	<b>3.28</b>	<b>0</b>	<b>18,000</b>

D-4G July 2003

## PERFORMANCE TESTS

# Sequence VIC (Modified VIB)

### SCOPE:

The Sequence VIB test is run in a Ford 4.6L SOHC V-8 engine with roller follower valve train. The testing sequence includes an extended period of operation to age the oil as both the initial level of fuel economy improvement and its retention with use are important. The modification to the VIB test is a 40-hour increase in phase II aging. Fuel consumption measurements are taken at several speed/load/temperature operating conditions and compared with the performance of fresh, baseline calibration oil tested under the same conditions. The fuel economy improvement is calculated by combining the individual condition results (stages) in a weighted manner based on correlation with vehicle EPA cycle driving.

The Sequence VIB test is designed to evaluate an engine oil's fuel economy performance relative to that of a full synthetic SAE 5W-30 baseline oil. The result is expressed as a percent improvement relative to this baseline oil. The VIB method of reporting fuel economy retention performance was set to reflect 4000 to 6000 miles of vehicle aging. The **VIC is designed to** increase this vehicle mileage simulation by about 40%, reflecting about 5600 to 8400 miles of vehicle aging.

←  
12/02

### TEST CONDITIONS:

- |            |   |
|------------|---|
| Engine:    | Ford 4.6L SOHC V-8  |
|            | - 16 hours (Aging Stage 1) followed by FEI data collection  |
| Operation: | - 120 additional hours (Aging Stage 2) aging at 135°C oil followed by another FEI data collection |

See page D-6 for actual measurement and aging.

The ASTM Sequence VI surveillance panel held a teleconference on November 30, 2001 to address

←  
12/01

what oil charge volume should be used for VIC testing. Since the VIC has 40 more hours of aging than the VIB, an increased oil charge is needed to assure sufficient oil level at end of test for stable fuel economy measurement. Work in the VIB has demonstrated that at low oil level, fuel economy measurement precision is degraded. Several oil charge volumes were proposed based on the relative increase in test length of the VIC versus the VIB. A minimal increase in initial oil charge of 360 ml over VIB practice was finally agreed. It was recognized that this is only about half the increased oil consumption one would expect from the added 40 hours of aging. Since the intent is to increase aging severity, a minimum oil charge was desired. If EOT oil level is found to be marginal, then oil pan modification will be considered to maintain adequate sump level.

Fuel economy calculation was briefly discussed. Since test length of the VIC is about 40% longer than the VIB, a fuel economy calculation using only BCB for FEI 1 and BCA for FEI 2 will be studied.

**The ASTM Sequence VI Surveillance panel met on February 12, 2002 to review VIC development test activity. A total of five tests had been conducted on reference oils. The VIC tests were slightly modified to collect candidate fuel consumption at the normal VIB FEI 2 point (96 aging hours). This allowed direct comparison, within a test, of the effect of the 40-hour VIC aging. These tests indicated that used oil properties (viscosity, oxidation, nitration, coefficient of friction) all continue to degrade with engine aging. However, the FEI 2 results for the VIB and VIC were essentially identical. A summary of this information is included as a D-5B thru D-5N (complete meeting minutes are available on the ASTM Test Monitoring Center web site [www.astmtmc.cmu.edu](http://www.astmtmc.cmu.edu)). The test developer is currently looking for an oil that will demonstrate poorer FEI 2 in a VIC relative to a VIB. To date none has been identified.**

←  
4/02

April 2002

The Sequence VI Surveillance panel met in Detroit on May 14. The panel was expected to make a final decision on the need for the VIC since data presented at the last VI surveillance panel indicated the VIC added no performance differentiation versus the VIB. At the May 14 meeting Ford, the test developer, highlighted three new test results indicating that the proposed Sequence VIC might result in poorer FEI 2 performance than experienced with the VIB. Ford plans to continue to pursue further testing of these oils to determine if the VIC can be technically justified. However, this effort will be structured so as not to delay GF-4 finalization. A final decision on Sequence VI selection for GF-4 is expected at the June 20 ILSAC/Oil meeting.

**At the September 5, 2002 ILSAC/Oil meeting, ILSAC announced that work on the VIC had been abandoned for GF-4. The Sequence VIB will be carried forward to GF-4 but with pass/fail limit performance increased.**

←  
12/02

# **SEQUENCE VIC DEVELOPMENT INITIAL DESIGN OF EXPERIMENT**

**DEARBORN, MI  
FEBRUARY 12, 2002**

**Barry Jecewski, Ford Motor Company  
Milton Johnson, Ford Motor Company  
Patrick Lai, Imperial Oil**

# DESIGN OBJECTIVES

- TO EXAMINE OR DEMONSTRATE THE FOLLOWING
  - A WIDE RANGE OF FORMULATION CHEMISTRY
  - PERFORMANCE DEGRADATION AFTER 40 HOURS OF ADDITIONAL AGING
  - EFFECT OF 360 mL ADDITIONAL OIL CHARGE
  - ENGINE PERFORMANCE AND OIL ANALYSIS COMPARISON
    - VISCOMETRICS
    - OXIDATION / NITRATION
    - COEFFICIENT OF FRICTION
    - DEPLETION OF P-O-C ABSORBANCE
  - REPEATIBILITY

# DESIGN PROTOCOL

- 3 OILS UTILIZED, 2 WITH ESTABLISHED PERFORMANCE LEVELS
  - TMC 1008 (SAE 5W30)
  - TMC 538 (SAE 5W20)
  - RO 182 (SAE 5W20)
- 2 TEST STANDS, PREVIOUSLY VIB REFERENCED
- 5 TESTS
  - 4 AT 6.36L INITIAL OIL CHARGE
  - 1 AT 6.00L INITIAL OIL CHARGE

# TEST PROTOCOL

- TESTS CONDUCTED AS PER VIB WITH FOLLOWING DIFFERENCES
  - INITIAL CANDIDATE OIL CHARGED WITH ADDITIONAL 0.36L (TOTAL 6.36L) FOR 4 OF 5 TESTS
  - ADDITIONAL 40 HOURS OF AGING AT VIB CONDITIONS TO A TOTAL OF 136 HOURS
  - 5-STAGE BSFC MEASUREMENTS AT 16, 96, AND 136 HOURS OF TOTAL AGING
  - SMALL (5 mL OR LESS) OIL SAMPLES TAKEN AT 12, 14, 16, 32, 48, 64, 80, 96, 104, 112, 120, 128, AND 136 HOURS OF AGING.
  - TIME PRO-RATED WEIGHTING\*\* TO CALCULATE FEI AT 16, 96, AND 136 HR
- \*\* SEPARATE PRESENTATION ON TPR WEIGHTING

# OVERALL RESULTS (FEI %)

<u>TEST #</u>	<u>OIL</u>	<u>PHASE 16</u>	<u>PHASE 96</u>	<u>PHASE 136</u>
<b>E8 - 329</b>	<b>TMC 1008</b>	<b>1.74</b>	<b>1.19</b>	<b>1.20</b>
<b>E8 - 330</b>	<b>TMC 538</b>	<b>2.05</b>	<b>1.68</b>	<b>1.62</b>
<b>W10 - 134</b>	<b>TMC 1008</b>	<b>1.76</b>	<b>1.18</b>	<b>1.30</b>
<b>W10 - 135</b>	<b>RO182</b>	<b>1.91</b>	<b>1.86</b>	<b>1.74</b>
<b>E8 - 332</b>	<b>TMC 1008-6L</b>	<b>2.04</b>	<b>1.01</b>	<b>1.17</b>

D-5F

# OBSERVATIONS – ENGINE DATA

- 3 DIFFERENT FAMILIES OF CHEMISTRY USED. NEED TO EXPAND TO MORE
- FOR THESE 3 OILS, LITTLE OR NO ADDITIONAL FEI DEGRADATION WITH EXTRA 40 HOURS OF AGING
- 360 mL OF EXTRA OIL CHARGE HAS NO SIGNIFICANT INFLUENCE ON FEI
- GOOD REPEATABILITY BETWEEN THE 2 STANDS USED DEMONSTRATED

## Approach

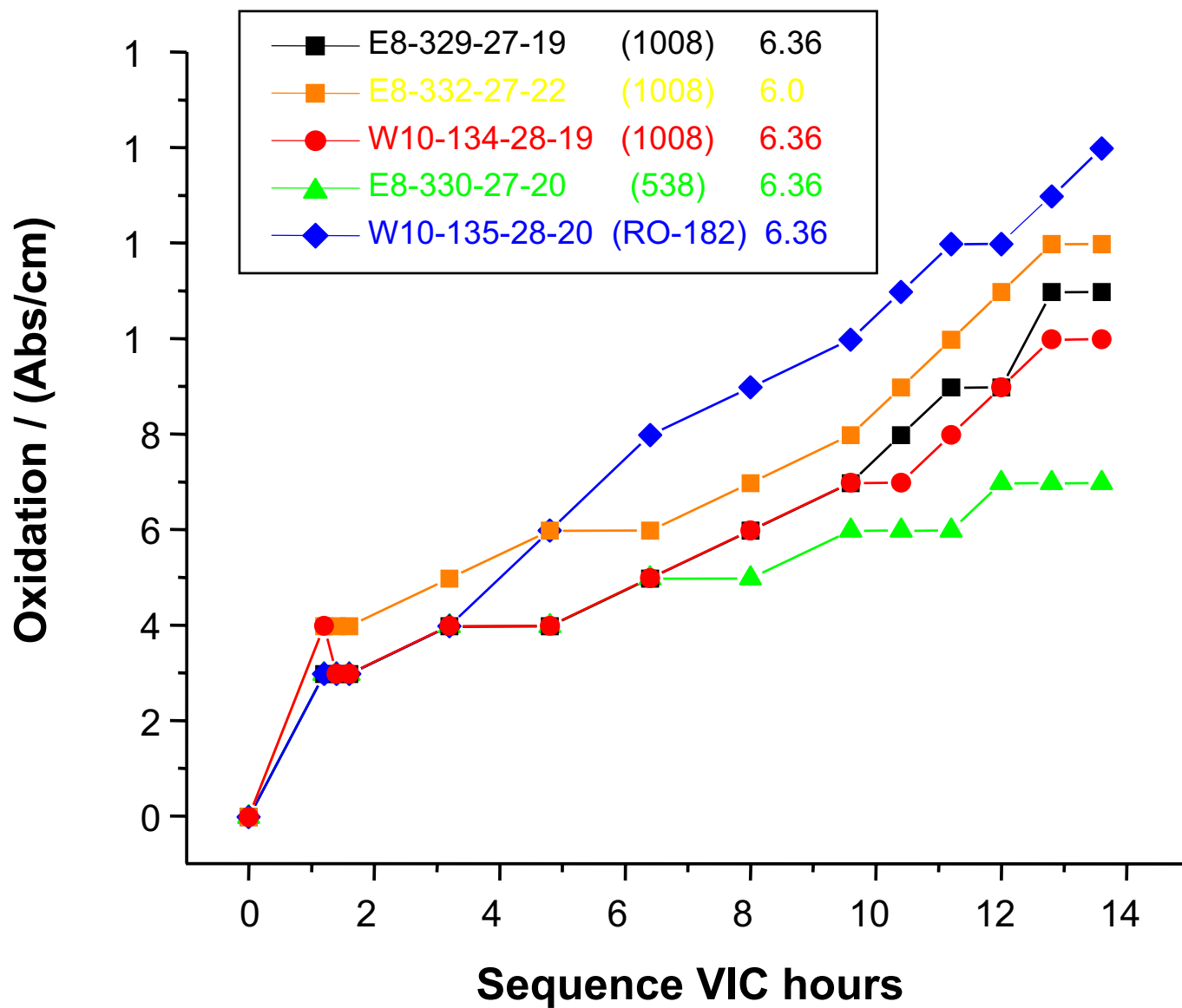
Determine effects of aging time on oil properties in extended length “Sequence VIC” testing.

- Three oils
  - Reference oils 1008 and 538
  - GF-4 prototype – RO-182
- Two stands

Monitor changes in oil as a function of aging time

- Infrared spectroscopy
  - Oxidation
  - Nitration
  - P-O-C (ZDTP) depletion
- Friction coefficient – HFRR
  - 30 min @ 105 °C, 1000 g load, 20 Hz, 1mm stroke
  - Report average value during last 10 minutes
- Viscosity – kinematic at 40 °C

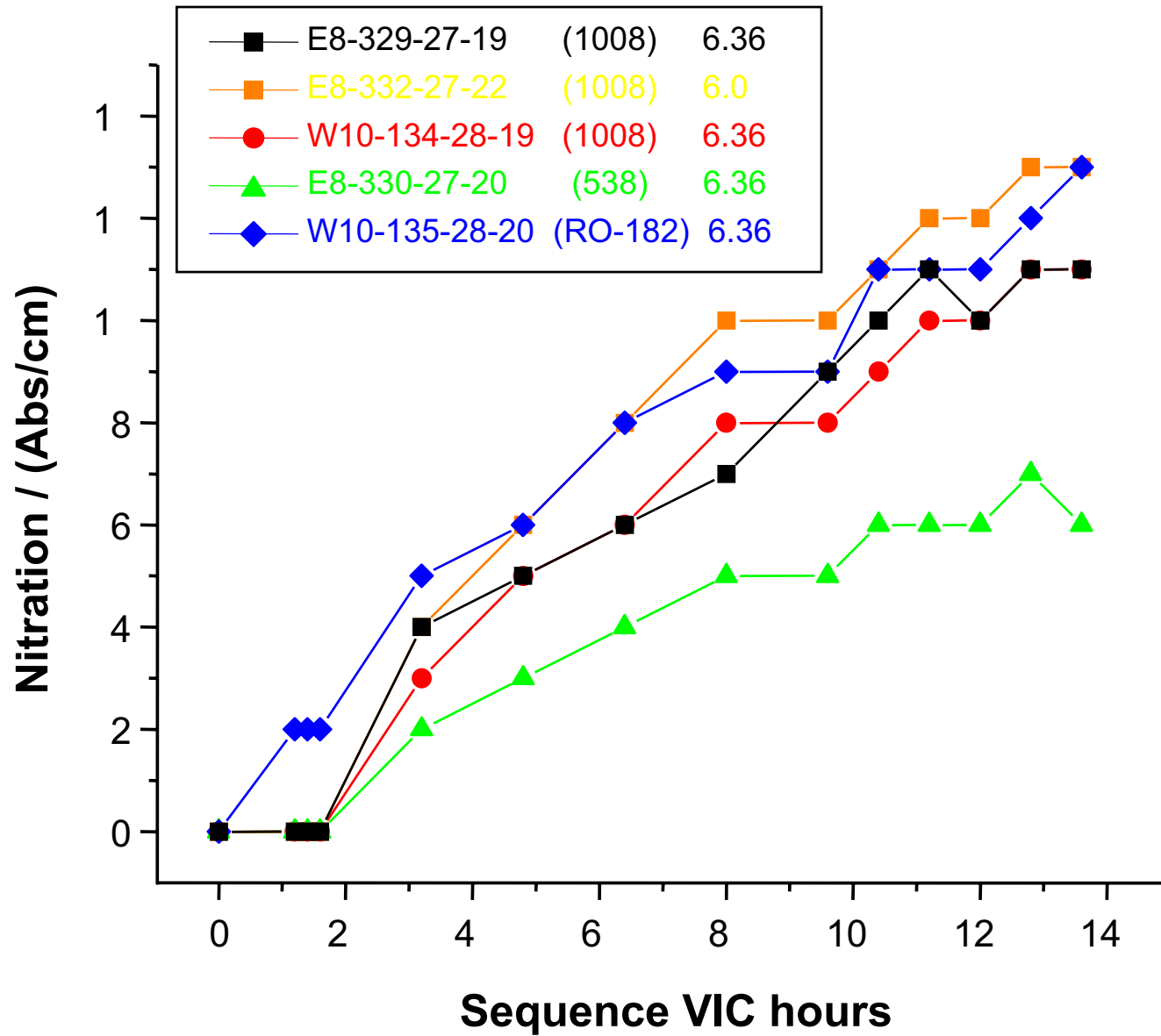
## All Tests



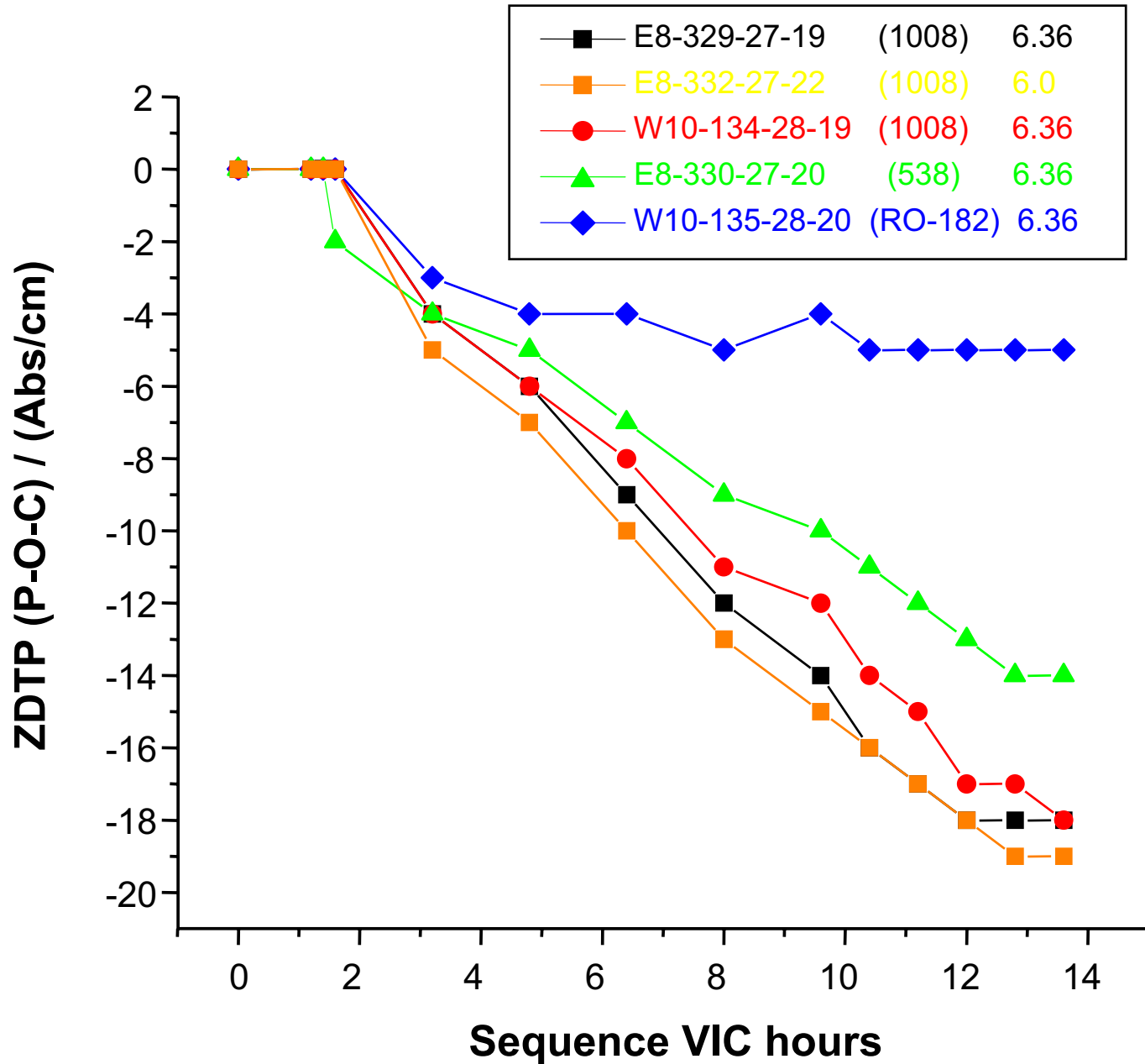
D-51

D-5J

## All Tests

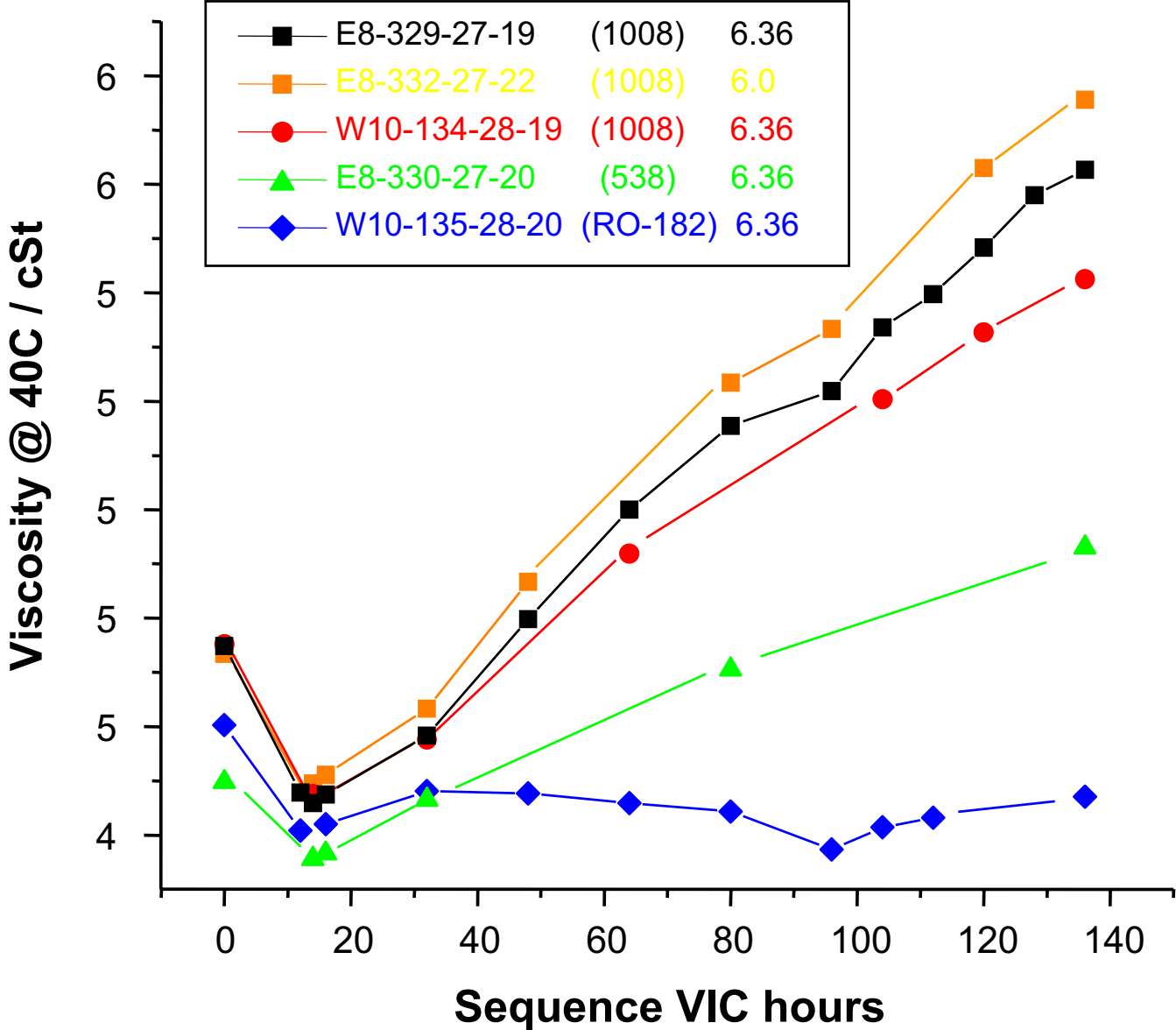


# All Tests



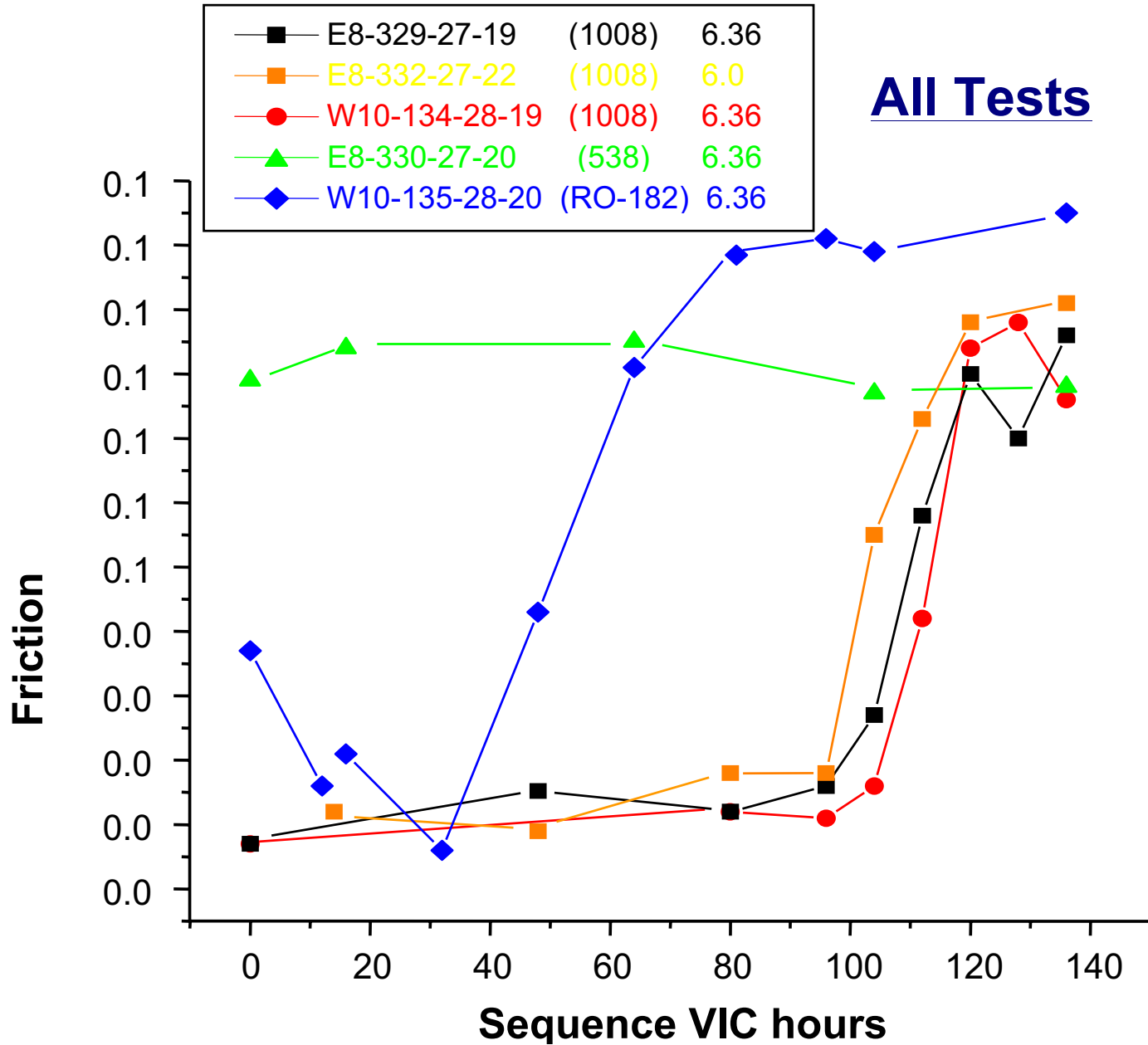
D-5K

# All Tests



D-5L

D-5M



## Conclusions

- Additional 360 mL oil reduces severity of aging.
- Extent of oxidation and nitration is low at 136 hours for all oils tested.
- Reference oils continue to age in uniform manner during additional 40 hr of aging.
- Some stand to stand variation noted
- Reference oil 538 oxidizes less and gives lower viscosity increase than 1008
- Prototype GF-4 oil (RO-182) controlled viscosity very well and gave low oxidation.

# Sequence VIB

## Fuel Economy Measurement and Aging Conditions

D-6

FE stage	Speed (rpm)	Torque (N.m)	Oil Temp. (°C)	Coolant Temp. (°C)	Comments
1	1500	98	125	105	New 'mixed' lubrication stage
2	800	26	105	95	VIA – Stage 1
3	800	26	70	60	VIA – Stage 2
4	1500	98	70	60	VIA – Stage 4
5	1500	98	45	45	VIA – Stage 5

Aging stage*	Speed (rpm)	Torque (N.m)	Oil Temp. (°C)	Coolant Temp. (°C)	Comments
1	1500	98	125	105	Same as VIA
2	2250	98	135	105	New

\* Blowby range: 5.3 – 9.0 (l/m)

## PERFORMANCE TESTS

# OPEST

### SCOPE:

The purpose of the OPEST (Oil Protection of Emission System Test) test is to evaluate the impact of engine oil on the degradation of catalyst efficiency. The objective is to have a performance based test as an alternative to a chemical restriction on engine oil phosphorus content. The OPEST development schedule is currently lagging the GF-4 specification launch timing schedule.

Several OPEST approaches have been investigated in pursuit of developing a performance based test for evaluating the impact of engine oil on exhaust catalyst durability. The most promising, and only option still under consideration, is the FOCAS (Fuel Oil Catalyst Aging System) bench rig.

### TEST CONDITIONS:

Still Under Development

Equipment:	Gas burner flow rig for aging (FOCAS)
Oil Injection rate:	28 gram s/hr.
Gas temperature:	580 - 650 C at oil injection point 580 - 640 C at catalyst inlet
Gas flow rate:	59 -52 SCFM
Test length	200 hours
Catalyst type:	Pd/Rd @ 9/1
Catalyst precious metal loading:	60 gram s /cubic foot 600 cells /square inch
Catalyst size:	3.66" dia. & 4.37" long

←  
6/02

June 2002

## PERFORMANCE TESTS

# OPEST

### STATUS :

Test development work is being conducted at SwRI and is funded with assets remaining from industry donations to the original engine test development work. Two OPEST development programs using the FOCAS rig have been conducted since late 1999 and these data have been more encouraging than was work with an engine-based test procedure. In April 2001, the OPEST II panel decided to allocate all remaining ASTM funds to a SwRI proposal for running four oils that have documented field test catalyst performance. The objective is to determine if the refined FOCAS procedure can adequately discriminate the performance of these oils. This program is expected to start around October 2001 and complete in mid 2002. If this work is successful, then further evaluation would be proposed at that time to complete FOCAS proveout. Any work beyond that already committed would need additional industry funding.

The OPEST panel met on May 15, 2002 to receive the interim (200 aging hours) FOCAS test results report from SwRI. The group agreed with SwRI that further aging would not be necessary and that the 200 hour aging protocol appeared to separate the relative performance of the two oil pairs similar to field test experience. A task force was established to develop a go-forward plan for test procedure proveout. Once a plan is agreed upon it will be presented to industry stakeholders to determine if funding can be secured. No further development funding is anticipated before 2003.

SwRI has posted the updated FOCAS development report on their OPEST Web site.

<http://www.swri.edu/pest/pest.htm>

User Name: astm seqvii  
Password: phosphorus15

←  
6/02

June 2002

- A 200 hour FOCAS procedure looks encouraging but a longer aging time is required. If this decision is taken, then SwRI would conduct further aging of the four catalysts.
- The FOCAS procedure does not appear to be viable for engine oil emission performance evaluation.

←  
4/02

**No matter which decision is arrived at in mid-May, an OPEST test could not be finalized in time to meet GF-4 specification development needs.**

SwRI will periodically update FOCAS development testing status on their OPEST web site.

<http://www.swri.edu/opest/opest.htm>

The user name is: astmseqvii  
The password is: phosphorus15

**April 2002**

## PERFORMANCE TESTS

# BRT (ASTM D 6557)

### SCOPE:

The BRT (Ball Rust Test) is an 18-hour bench test procedure in which a hydraulic lifter ball in test oil is subjected to acids and air. The ball is rated automatically for reflectance intensity as a measure of surface area corrosion. The test performance parameter is gray value rating.

The BRT is designed to evaluate an oil's ability to inhibit rust of internal engine parts in cyclic cold and hot operation where significant water and acid buildup can occur.

### TEST CONDITIONS:

Equipment:	Hydraulic lifter ball in 20 cc syringe with 10 cc of test oil on shaker table
Acid Solution:	Acetic acid/HBr/HCl/deionized water
Acid Addition:	0.19 ml/hr.
Air Flow:	40 cc/minute
Temperature:	48°C
Shaker Speed:	300 RPM
Test Length:	18 hours

## PERFORMANCE TESTS

# Sequence VG

### SCOPE:

The Sequence VG is designed to evaluate an oil's ability to prevent excessive sludge and varnish deposits in short trip/low temperature driving conditions. The Sequence VG cycles between cold and hot operation to promote the generation of acid and fuel in the oil.

The test performance parameters are Avg. engine sludge, Rocker arm cover sludge, Avg. engine varnish, Piston skirt varnish, Oil screen clogging, and ring sticking. For GF-4, the test developer (Ford) is investigating the addition of a valve lifter roller pin wear performance requirement.

### TEST CONDITIONS:

Engine:	Ford 4.6L SOHC V-8
Operation:	Three stage cycle each 4 hours
Time (minutes):	120/75/45
Speed (RPM):	1200/2900/700
Manifold pressure (KPa absolute):	69/66/record
Oil temperature (°C):	68/100/45
Rocker cover coolant temp. (°C):	29/85/29
Engine coolant temp. (°C):	57/85/45
Test length (hours):	216
Fuel:	Haltermann fuel unleaded (Clear)

## PERFORMANCE TESTS

# Sequence IVA

### SCOPE:

The Sequence IVA is a JASO (KA24E) test modified to conform to ASTM requirements. The test evaluates valve train wear under low temperature and low speed operation. The test performance parameter is avg. cam lobe wear measured at seven locations on each lobe.

The Sequence IVA is designed to evaluate an oil's ability to prevent cam lobe wear in slider valve train design engines operated at low temperature, short trip, "stop and go" conditions.

### TEST CONDITIONS:

Engine:	Nissan 2.4L inline 4 cylinder
Engine speed:	800 and 1500 RPM cycles
Engine torque (N-m)	25
Oil temperature (°C):	50 and 60 cycle
Coolant temperature (°C):	50 and 55 cycle
Cycle duration (min):	50 low speed/10 high speed
Test Length:	100 hours
Fuel:	Haltermann fuel unleaded (dyed green)

## PERFORMANCE TESTS

### Sequence VIII

#### SCOPE:

The Sequence VIII test evaluates the ability of an oil to minimize copper/lead bearing corrosion and its resistance to permanent viscosity loss due to mechanical shear. The test performance parameters are bearing weight loss and 10-hour stripped viscosity.

#### TEST CONDITIONS:

Engine:	Labeco single cylinder
Engine speed (RPM):	3150
Fuel consumption (lb/hr):	4.96
Oil temperature (°C):	143 (135 for 10 grade)
Coolant temperature (°C):	93
Test length (hours):	40
Fuel:	Haltermann fuel unleaded (Dyed green)
Air/Fuel:	13.43/1

## PERFORMANCE TESTS

# MHT-4 TEOST

### SCOPE:

The MHT-4 TEOST is a bench test developed to correlate with piston deposit performance experienced when engines are run under high power/high temperature conditions. The test performance parameter is weight of deposit in mg.

### TEST CONDITIONS:

Equipment	Savant TEOST
Test length	24 hours
Depositor oil flow	0.25 g/min.
Oil volume	8.50 g
Depositor rod temp.	285°C
Air flow	10 ML/min
Catalyst concentration	0.114 g/g oil
Catalyst	Pb/Fe/Sn