

COAST SIDE PINION SCORING

Unit of Measure: % Scoring

Gear Batch P8L604

Reference Oil	Mean	Standard Deviation
115	25.3	4.58
116	22.9	4.81
116-1	22.9	4.81

COAST SIDE PINION SCORING

Unit of Measure: % Scoring

Gear Batch P4L806

Reference Oil	Mean	Standard Deviation
116	25.1	5.49
116-1	25.1	5.49

COAST SIDE PINION SCORING

Unit of Measure: % Scoring

Gear Batch P8L119

Reference Oil	Mean	Standard Deviation
116	23.0	5.49
116-1	23.0	5.49

COAST SIDE PINION SCORING

Unit of Measure: % Scoring

Gear Batch P8T025A

Reference Oil	Mean	Standard Deviation
116-1	23.0	5.49
117	23.0	5.49

COAST SIDE PINION SCORING

Unit of Measure: % Scoring

Gear Batch P8AD078X

Reference Oil	Mean	Standard Deviation
116-1	23.0	5.49
117	23.0	5.49

COAST SIDE PINION SCORING

Unit of Measure: % Scoring

Gear Batch P8AD132 (Pinion ID's C1L446, C1L637)

Reference Oil	Mean	Standard Deviation
116-1	23.0	5.49
117	23.0	5.49

L-42 Reference Oil Targets (continued)						
Oil	Gear Batch	N	Effective Dates		Coast Side Pinion Scoring	
			From ¹	To ²	\bar{X}	s
116-1	P8L123 ⁷	--	3-1-09	***	22.9	4.81
	P8L205 ⁷	--	3-1-09	***	22.9	4.81
	P8L327 ⁷	--	3-1-09	***	22.9	4.81
	P8L604 ⁷	--	3-1-09	***	22.9	4.81
	P4L806 ⁷	--	3-1-09	***	25.1	5.49
	P8L119	10	3-22-09	***	23.0	5.49 ⁸
	P8T025A	10	4-17-12	***	23.0 ⁹	5.49 ⁹
	P8AD078X	10	3-7-15	***	23.0 ⁹	5.49 ⁹
117	P8T025A	10	5-29-14	***	23.0 ¹⁰	5.49 ¹⁰
	P8AD078X	10	3-7-15	***	23.0 ^{9,10}	5.49 ^{9,10}
	P8AD132 (Pinion ID's C1L446, C1L637)	10	11-9-17	***	23.0 ^{9,10}	5.49 ^{9,10}

1 Effective for all tests completed on or after this date	6 Targets based on gear batch P8L604
2 ***currently in effect	7 Targets based on oil 116
3 Targets based on oil 114	8 Standard deviation based on gear batch P4L806
4 Targets based on oil 114-1	9 Carried over from previous hardware batch
5 Targets based on gear batch P8L327	Target based on 116/116-1. A +6% correction factor is used with this oil to maintain parity with 116/116-1

30. L-33-1 LTMS Requirements

The following are the specific L-33-1 calibration test requirements.

A. Reference Oils and Critical Parameter

The critical parameter is Final Rust. The reference oils required for test stand and test laboratory calibration are reference oils accepted by the ASTM L-33-1 Surveillance Panel. The mean and standard deviations for the current reference oils for the critical parameter are presented below.

FINAL RUST
Unit of Measure: Merits
Gear Versions V99.1 & V01.1

Reference Oil	Mean	Standard Deviation
123	8.560	0.230
123-2	8.740	0.260
151-3	9.640	0.250
155	9.580	0.250
155-1	9.580	0.250

FINAL RUST
Unit of Measure: Merits
Gear Version AAM K2XX & T1XX

Reference Oil	Mean	Standard Deviation
123-2	8.51	0.35
155-1	9.47	0.16
155-2	9.47	0.16

B. Acceptance Criteria

1. New Test Stand

- A minimum of two (2) operationally valid calibration tests, with no stand Shewhart severity alarms, must be conducted on any approved reference oils assigned by the TMC.
- All operationally valid calibration test results must be charted to determine if the test stand is currently “in control” as defined by the control charts from the Lubricant Test Monitoring System.

2. Existing Test Stand

L-33-1 Reference Oil Targets						
Oil	Gear Version	n	Effective Dates		Rust	
			From ¹	To	\bar{X}	s
121	V94.1	12 ²	6-5-96	4-19-00	9.370 ²	0.280 ²
	V95.1	12 ²	6-5-96	4-19-00	9.370 ²	0.280 ²
121-1	V94.1	--	1-19-98	4-29-99	9.370 ³	0.280 ³
	V94.1	45 ²	4-30-99	11-17-00	9.390 ²	0.218 ²
	V95.1	--	1-19-98	4-29-99	9.370 ³	0.280 ³
	V95.1	45 ²	4-30-99	11-17-00	9.390 ²	0.218 ²
	V99.1	8	4-20-00	11-17-00	9.830	0.260 ⁴
121-2	V94.1	--	12-14-99	11-17-00	9.390 ⁵	0.218 ⁵
	V95.1	--	12-14-99	11-17-00	9.390 ⁵	0.218 ⁵
	V99.1	--	4-20-00	11-17-00	9.830 ⁶	0.260 ⁴
123	V94.1	54 ²	5-5-95	4-19-00	9.000 ²	0.330 ²
	V95.1	54 ²	5-5-95	4-19-00	9.000 ²	0.330 ²
	V99.1	12	6-11-02	8-24-04	8.430	0.390
	V01.1	--	11-25-02	8-24-04	8.430 ¹⁰	0.390 ¹⁰
	V99.1 & V01.1	30	8-25-04	***	8.560	0.230
123-1	V94.1	13 ⁷	4-20-00	11-17-00	8.240 ⁷	0.330 ⁸
	V95.1	--	12-14-99	4-19-00	9.000 ⁹	0.330 ⁹
	V95.1	13 ⁷	4-20-00	11-17-00	8.240 ⁷	0.330 ⁸
	V99.1	13 ⁷	4-20-00	11-17-00	8.240 ⁷	0.330 ⁸
123-2	V99.1	--	11-25-02	8-24-04	8.430 ¹⁰	0.390 ¹⁰
	V99.1 & V01.1	--	8-25-04	6-1-06	8.560 ⁹	0.230 ⁹
	V99.1 & V01.1	15	6-2-06	***	8.740	0.260
	AAM K2XX	10	6-24-16	06-28-17	8.05	0.43
	AAM K2XX	19	6-29-17	11-07-17	8.09	0.41
	AAM K2XX	22	11-08-17	0-01-20	8.12	0.38
	AAM K2XX	19	01-02-20	08-31-20	8.37	0.39
	K2XX & T1XX	37	09-01-20	***	8.51	0.35
151-3	V99.1	13	6-11-02	8-24-04	9.690	0.350
	V01.1	--	11-25-02	8-24-04	9.690 ¹¹	0.350 ¹¹
	V99.1 & V01.1	30	8-25-04	***	9.640	0.250
155	V99.1 & V01.1	--	6-2-06	---	9.580	0.250 ¹²
155-1	V99.1 & V01.1	--	4-4-12	---	9.580	0.250 ¹²
	AAM K2XX	9	6-24-16	06-28-17	9.26	0.12
	AAM K2XX	20	6-29-17	11-07-17	9.24	0.19
	AAM K2XX	23	11-08-17	01-01-20	9.25	0.22
	AAM K2XX	20	01-02-20	08-31-20	9.47	0.13
	K2XX & T1XX	42	09-01-20	***	9.47	0.16
155-2	K2XX & T1XX	-	08-25-21	***	9.47	0.16

- 1 Effective for all tests completed on or after this date. 7 Based on V99.1 and V95.1 data.
2 Based on V94.1 & V95.1 data. 8 Based on lab pooled s of V94.1 & V95.1 data (all blends of oil 123).
3 Based on oil 121 data. 9 Based on oil 123 data.
4 Based on lab pooled s of V94.1 & V95.1 data (all blends of oil 121). 10 Based on V99.1 data on oil 123.
5 Based on oil 121-1 data. 11 Based on V99.1 data on oil 151-3.

43. D7528 ROBO Test LTMS Requirements

The following are the specific D7528 ROBO Test calibration requirements.

A. Reference Oils and Critical Parameters

1. The critical pass/fail parameter is MRV Apparent Viscosity of the aged oil in transformed units. The reference oils, performance targets and acceptance criteria required for the test stand calibration with the TMC are listed in Table 1 and have been approved by the ASTM D02.B0.07 ROBO Surveillance Panel. Table 2 shows historic ROBO reference oil targets (also see appendix A-53).

Table 1
Current Reference Oils
MRV VISCOSITY
Unit of Measure: LN(MRV)

D7528 (ROBO) Aged Oil MRV Acceptance Bands, mPa's and ln(mPa's)								
Oil	n	Natural Log Transformed Mean (ln)	Mean in Original Units	s.d. (ln)	95%	95%	95%	95%
					band in mPa's Min ¹	band in mPa's Max ¹	Bands Min (ln)	Bands Max (ln)
434-2	36	² 10.9284	² 55,737	0.1551	² 41,126	² 76,008	² 10.6244	² 11.2386
434-3	22	² 10.8172	² 49,871	0.1389	² 37,987	² 65,473	² 10.5450	² 11.0894
435-1	22	11.0416	62,420	0.20295	⁴ 44570	92910	⁴ 10.7048	11.4394
436	36	² 10.3319	² 30696	0.1290	23840	39525	10.0791	10.5847

¹ 95% bands in mPa's are listed for information purposes only; the transformed values will be used to judge acceptance in all cases.

² A bias adjustment has been applied to the mean of reference oils 434-2, 434-3, 436 and 438-2 to account for biases observed in the TMC reference data during the periods that each oil target dataset was generated. The 95% confidence range reflects the inclusion of the bias adjustments.

³ The minimum value for Reference oil 435 is fixed at 60,000 (11.0021 in transformed units) and not a true 95% minimum as calculated from the statistics.

⁴ The minimum value for reference oil 435-1 is based on -1.66 standard deviations from the target mean (to match the range previously approved for oil 435 min), so is not actually a 95% confidence range. A 95% confidence range would use 1.96 standard deviations from target mean.

Table 2
 Historic Reference Oils (information only)
 MRV VISCOSITY
 Unit of Measure: LN(MRV)

D7528 (ROBO) Aged Oil MRV Acceptance Bands, mPa·s and ln(mPa·s)								
Oil	n	Natural Log Transformed Mean (ln)	Mean in Original Units	s.d. (ln)	95%	95%	95%	95%
					band in mPa·s Min ¹	band in mPa·s Max ¹	Bands Min (ln)	Bands Max (ln)
434-1	13	10.6599	42,612	0.1672	30,706	59,136	10.3322	10.9876
435	15	11.4895	97,685	0.2932	³ 60,000	173,546	³ 11.0021	12.0642
438	14	10.2676	28,785	0.2037	19,308	42,912	9.8683	10.6669
438-2	19	² 10.5404	² 37813	0.2596	² 22,734	² 62,894	² 10.0316	² 11.0492

¹ 95% bands in mPa·s are listed for information purposes only, the transformed values will be used to judge acceptance in all cases.

² The minimum value for Reference oil 435 is fixed at 60,000 (11.0021 in transformed units) and not a true 95% minimum as calculated from the statistics.

2. EOT MRV (MRVEOT) viscosity values >400,000 mPa·s shall be reported as >400000.
3. EOT volatiles (VOLEOT) for the reference oils, in a properly run test, should never reach or exceed 60%. Tests with EOT volatility $\geq 60\%$ will be declared operationally invalid.
4. Tests with EOT yield stress (MRVYSEOT) measured or reported at anything other than <35 will be declared operationally invalid. An exception is allowed for reference oil 434-3 only, where any yield stress measured at >35 Pa does not invalidate the test.

B. Acceptance Criteria

1. New Laboratory/New Test Stand(s)

- a. The TMC calibration auditing system calibrates individual test stands at individual laboratories. There are no requirements to bring a lab into TMC calibrated status, there are only requirements to bring individual test stands into TMC calibrated status, as follows:
- b. Prior to obtaining calibration test oils from the TMC, new laboratories introducing a test stand must demonstrate their stand can successfully run all three (3) current TMC calibration oils within the TMC acceptance bands. Upon acceptance of these results by the TMC, the lab may request the two test calibration.
- c. A minimum of two (2) operationally valid calibration tests which fall within the acceptance bands for the oils assigned are required to calibrate a stand for the first time. These must be back-to-back consecutive runs on the same test

stand, though exceptions can be made at the sole discretion of the TMC for operational fails for reasons that would be considered to have had no bearing on the operational performance of the test stand for subsequent tests (for example, a power failure).

- d. Passing two back-to-back consecutive TMC calibrations places the new test stand in TMC calibrated status. Both tests must pass on operational and statistical criteria.
- e. TMC calibrated status of a test stand is valid for no more than 50 days from date completed of a valid TMC calibration (that is, the end of the test's 40-hour oil oxidation heating cycle), or no more than 15 subsequent test starts on the stand (as counted sequentially by run number; see Item 3), whichever comes first. To renew the calibration at the end of the calibration period, see Item 2 for Existing Laboratory/Test Stand(s).

2. Existing Laboratory/New Test Stand(s)

- a. The TMC calibration auditing system calibrates individual test stands at individual laboratories. There are no requirements to bring a lab into TMC calibrated status, there are only requirements to bring individual test stands into TMC calibrated status, as follows:
- b. A minimum of two (2) operationally valid calibration tests which fall within the acceptance bands for the oils assigned are required to calibrate a stand for the first time. These must be back-to-back consecutive runs on the same test stand, though exceptions can be made at the sole discretion of the TMC for operational fails for reasons that would be considered to have had no bearing on the operational performance of the test stand for subsequent tests (for example, a power failure).
- c. Passing two back-to-back consecutive TMC calibrations places the new test stand in TMC calibrated status. Both tests must pass on operational and statistical criteria.
- d. TMC calibrated status of a test stand is valid for no more than 50 days from date completed of a valid TMC calibration (that is, the end of the test's 40-hour oil oxidation heating cycle), or no more than 15 subsequent test starts on the stand (as counted sequentially by run number; see Item 3), whichever comes first. To renew the calibration at the end of the calibration period, see Item 2 for Existing Laboratory/Test Stand(s).

3. Existing Laboratory/Existing Test Stand(s)

- a. An existing TMC calibrated test stand, or one where the TMC calibrated status had expired within the past 150 days, can renew its TMC calibrated status by

demonstrating a successful calibration on another single TMC blind calibration audit. The test must pass on both operational and statistical criteria.

- b. TMC calibrated status of an existing test stand is valid for no more than 50 days from date completed of a valid TMC calibration (that is, the end of the test's 40-hour oil oxidation heating cycle), or no more than 15 subsequent test starts (as counted sequentially by run number) on the stand, whichever comes first. Test stands that exceed these time/run specifications are considered to be out of calibration for TMC monitoring purposes.
- c. A stand that has been out of TMC calibration for more than 150 days from the prior TMC calibration expiration date will require New Test Stand calibration as listed in B.2.b through B.2.d. of this document.
- d. A stand must pass the TMC calibration within two operationally valid test runs. If a stand cannot produce a calibration test that falls into the acceptance bands for the assigned oil within two operationally valid runs. Renewing calibration on that stand will require the two test calibration as listed in B.2.b through B.2.d.
- e. Changing the vacuum control valve set point, exchanging the reactor vessel or the vacuum pump, or changing the heating voltage setting by more than ± 1 volt on a stand for any reason voids any current TMC calibrated status. Renewing calibration on that stand will require the two test calibration as listed in B.2.b through B.2.d.

4. Tracking and Reporting Stand Runs

- a. Tracking a stands calibration status by run number will be effected by tracking and reporting Instrument ID and Run Number to the TMC. Run Number shall be a consecutive integer count of test starts. Instrument ID and Run Number are separate fields on the approved data dictionary. An example is:

Instrument ID: 1

Run Number: 1234

Instrument ID shall not change for the entire history of a TMC monitored test stand.

Run Number shall be increased incrementally by one (1) for each new test start, regardless of whether or not the test runs to completion, or whether or not the run is a TMC calibration attempt.

- b. Track reactor vessels within a lab by assigning a unique 3 digit (alpha and/or numeric) ID to each vessel.

5. Reference Oil Assignment:

Of the two tests required to bring a new stand into TMC calibrated status, the tests shall be conducted on reference oil 434-1 or 438 (or approved reblends of either), and 435-1,

assigned in random order. Once a stand has attained TMC calibrated status (existing test stand), 100% of the scheduled calibration tests should be conducted on a semi-randomly assigned reference oil from the currently accepted set. A preference for assignment shall be as follows:

Oil	% assigned*
434-1 or 434-2 or 434-3	25%
435-1	50%
438	25%

6. Removal of Test Stands from the System

The laboratory must notify the TMC when removing a stand from the system. No reference oil data shall be removed from the TMC's data base of prior TMC calibrations or calibration attempts. Return of the stand to the system will be evaluated based on section B.1.b through B.1.d above.

7. Introduction of New or Re-Blended Reference Oils

Introduction of new or replacement reference oils will be conducted at the discretion of the surveillance panel. Participating laboratories may be asked to donate tests on the new oil(s) to establish baseline performance in the ROBO test. The number of tests requested will be sufficient to rigorously evaluate the oil's performance (typically a minimum of 12 tests total among all the participating labs). Preliminary statistical performance targets and acceptance criteria will be established by the surveillance panel, and those values will be re-assessed as the TMC collects additional calibration data.

D7528 ROBO Test Reference Oil Targets					
Oil	N	Effective Dates		LN(EOT MRV)	
		From ¹	To ²	\bar{X}	s
434-1	13	20080801	20200901	10.6599	0.1672
434-2	5	20170713	20180727	10.941	0.1672
	36	20180728	***	10.9284	0.1551
434-3	13	20191101	20211031	10.8411	0.1342
	22	20210201	***	10.8172	0.1389
435	15	20080801	20110928	11.4895	0.2932
435-1	22	20100408	***	11.0416	0.20295
436	17	20210429	20211020	10.3437	0.1605
	36	20211021	***	10.3319	0.1290
438	14	20080801	20210930	10.2676	0.2037
438-2	10	20190221	20191031	10.4421	0.2322
	19	20191101	20210930	10.5404	0.2596

- 1 Effective for all tests completed on or after this date.
- 2 *** = currently in effect.

40. D6335 (TEOST) Thermo-Oxidation Engine Oil Simulation Test LTMS Requirements

The following are the specific D6335 Determination of High Temperature Deposits by Thermo-Oxidation Engine Oil Simulation Test calibration requirements.

A. Reference Oils and Critical Parameters

The critical pass/fail parameter is Total Deposit Weight, in mg. The reference oils, performance targets and acceptance criteria required for the test stand calibration with the TMC are listed in Table 1 and have been approved by the ASTM D02.B0.07 TEOST Surveillance Panel.

Table 1
D6335 (TEOST) Reference Oil Targets and Acceptance Bands Effective 20190404

						Acceptance Bands*	
						95%	
Test	Oil Code	Parameter	n	Mean	sR	Lower	Upper
TEOST by	75-1	Total Deposit wt. (mg)	51	54.80	6.75	41.6	68.0
D6335	435-2	Total Deposit wt. (mg)	30	28.71	4.76	19.4	38.0

$$*95\% \text{ Acceptance Bands} = \text{Mean} \pm (1.960 \times \text{sR})$$

B. Acceptance Criteria

1. New Laboratory/Test Stand(s)

- a. The TMC calibration auditing system calibrates individual test stands (instruments) at individual laboratories. There are no special requirements to bring a LAB into TMC calibrated status, there are only requirements to bring individual test stands into TMC calibrated status, as follows:
- b. A minimum of two (2) operationally valid calibration tests which fall within the acceptance bands for the oils assigned are required to calibrate a stand for the first time. These must be back-to-back consecutive runs on the same test stand, though exceptions can be made at the sole discretion of the TMC for operational fails for reasons that would be considered to have had no bearing on the operational performance of the test stand for subsequent tests (for example, a power failure)
- c. Passing two back-to-back consecutive TMC calibrations places the new test stand in TMC calibrated status. Both tests must pass on operational and statistical criteria.
- d. TMC calibrated status of a test stand is valid for no more than 90 days from date completed of a valid TMC calibration (that is, the end of the test's 24-hour

D6335 (TEOST) Thermo-Oxidation Engine Oil Simulation Test Reference Oil Targets					
Oil	N	Effective Dates		Total Deposits	
		From ¹	To ²	\bar{X}	s
71	27	19900101	20130414	51.79	4.79
71-1 ³		20090113	20130414	51.79	4.79
72	27	19000101	20130414	26.72	3.46
72-1 ⁴		20090113	20130414	26.72	3.46
75	14	20110108	20130414	55.16	5.68
75	30	20130415	20210831	53.66	6.56
75-1	16	20190404	20211102	56.9	5.02
75-1	51	20211103	***	54.8	6.75
435-2	15	20110108	20130414	26.95	2.86
435-2	30	20130415	***	28.71	4.76

- 1 Effective for all tests completed on or after this date.
- 2 *** = currently in effect.
- 3 Targets carried over from oil 71
- 4 Targets carried over from oil 72

7. VH LTMS Requirements

The following are the specific VH calibration test requirements.

A. Reference Oils and Critical Performance Criteria

The critical performance criteria are Average Engine Sludge (AES), Rocker Cover Sludge (RAC), Average Engine Varnish (AEV50), and Average Piston Varnish (APV50). Number of Hot Stuck Rings is a discrete parameter and is monitored for occurrence only. The reference oils required for test stand and test laboratory referencing are reference oils accepted by the ASTM Sequence V Surveillance Panel. The means and standard deviations for the current reference oils for each critical performance criterion are presented below.

AVERAGE ENGINE SLUDGE (AES)

Unit of Measure: Merits

Reference Oil	Mean	Standard Deviation
931	8.00	0.60
940	6.47	0.49
1011	8.43	0.57
1011-1	8.43	0.57

ROCKER COVER SLUDGE (RAC)

Unit of Measure: $\ln(10\text{-RAC})$

Reference Oil	Mean	Standard Deviation
931	0.2283	0.5715
940	0.9155	0.2260
1011	-0.5294	0.1924
1011-1	-0.5294	0.1924

AVERAGE ENGINE VARNISH (AEV50)

Unit of Measure: Merits

Reference Oil	Mean	Standard Deviation
931	8.97	0.30
940	8.77	0.28
1011	9.26	0.21
1011-1	9.43	0.21

AVERAGE PISTON VARNISH (APV50)

Unit of Measure: Merits

Reference Oil	Mean	Standard Deviation
931	8.35	0.60
940	7.35	0.64
1011	8.67	0.48
1011-1	8.96	0.48

NUMBER OF HOT STUCK RINGS

Unit of Measure: Count

Reference Oil	Maximum Allowable
931	0
940	0
1011	0
1011-1	0

Any test failing on hot stuck rings is not chartable and must be re-run.

B. Acceptance Criteria

1. New Test Lab – a minimum of three valid calibration tests are required to establish a new lab.

a. The first two stands in a laboratory

- A minimum of two (2) operationally valid calibration tests and/or matrix tests, with no Level 3 e_i alarms must be conducted in a new laboratory on any approved reference oils.
- Note that industry matrix runs may be included, as well as reference runs, at the discretion of the surveillance panel.
- Following the necessary tests, check the status of the control charts and follow the prescribed actions

b. Third and subsequent stands in a laboratory

- New test stands in an existing lab may calibrate with one test provided e_i Level 1 limits are not exceeded. Otherwise a second test is required for calibration.
- For an existing test stand in an existing lab run one test.
- Following the necessary tests, check the status of the control charts and follow the prescribed actions

Sequence VH Reference Oil Targets												
Oil	n	Effective Dates		AES		RAC		AEV50		APV50		Hot Stuck Rings
		From ¹	To ²	\bar{X}	s	\bar{X}	s	\bar{X}	s	\bar{X}	s	Maximum Allowable
931	6	20210316	***	8.00	0.60	0.2283	0.5715	8.97	0.30	8.35	0.60	0
940	7	20170128	***	6.47	0.49	0.9155	0.2260	8.77	0.28	7.35	0.64	0
1009	8	20170128	20211115	7.21	0.44	0.0515	0.3139	8.81	0.40	7.89	0.74	0
1011	7	20170128	***	8.43	0.57	-0.5294	0.1924	9.26	0.21	8.67	0.48	0
1011-1	7	20220104	***	8.43	0.57	-0.5294	0.1924	9.43	0.21	8.96	0.48	0