LUBRICANT TEST MONITORING SYSTEM

ASTM Test Monitoring Center
Requirements for Engine Test
Stand/Laboratory Calibration

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Acknowledgment

The Lubricant Test Monitoring System (LTMS) described in this document is the result of efforts of the American Chemistry Council (ACC) Statistical Engine Test Work Group (SETWG) of the ACC Product Approval Protocol Task Group (PAPTG). The SETWG applied a logical and data based analytical approach to available ASTM calibration test data in the development of the LTMS. This system of managing lubricant engine test severity (bias) and precision was presented to the ASTM Technical Guidance Committee of the Test Monitoring Board in October, 1991 by the ACC PAPTG. The LTMS was subsequently adopted for use by ASTM Surveillance Panels.

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1. Lubricant Test Monitoring System Control Charts

Test stands and test laboratories are calibrated by the ASTM Test Monitoring Center (TMC). Calibration is in terms of both test severity and precision and is checked by the application of the control charts in the Lubricant Test Monitoring System (LTMS) to operationally valid reference oil test results. The purpose of the control charts is to monitor and track both large abrupt changes and smaller consistent trends in both test severity and precision. The Shewhart charts check for the abrupt changes while the Exponentially Weighted Moving Average (EWMA) charts check for consistent changes and trends over time. The Moving Standard Deviation (MSD) chart is used as an alternative to the EWMA chart for monitoring precision. The five control charts are listed below:

1. Shewhart Chart for Monitoring Severity
2. Shewhart Chart for Monitoring Precision
3. EWMA Chart for Monitoring Severity
4. EWMA Chart for Monitoring Precision
5. MSD Chart for Monitoring Precision

A. Control Chart Construction

This section outlines the construction of the five control charts that constitute this Lubricant Test Monitoring System. An example is provided in Exhibits I-III.

1. Shewhart Chart for Monitoring Severity

The vertical axis of this control chart represents the standardized calibration test results (Y). These results are plotted against completion date order (integer) which is on the horizontal axis. Y is calculated as follows:

$$Y_i = \frac{T_i - \text{MEAN}}{\text{STANDARD DEVIATION}}$$

T_i = Test result at test order i in appropriate units (see applicable test type in Section 2).

Y_i = Standardized test result at test order i. Standardized test result with the mean and the standard deviation of reference oil (in appropriate units) used in the calibration test.

The following are the control chart limits for the Shewhart chart for monitoring severity (Y plotted against completion date order).

$$0 \pm K$$

K is a constant that determines the chart's estimated false detection rate. The false detection rate is the percentage of time that a plotted result will fall outside the control limits when, in fact, no change in the process has occurred. As K increases, the false detection rate decreases. However, the false detection rate must be balanced with the chart's sensitivity to real changes in the process. This sensitivity is diminished as K increases. K is test type specific.

2. Shewhart Chart for Monitoring Precision

The vertical axis of this control chart represents the standardized calibration test moving ranges (R). These results are plotted against completion date order (integer) which is on the horizontal axis. R is calculated as follows:

$$R_i = \frac{\sqrt{|Y_i - Y_{i-1}|} - 0.969}{0.416}$$

R_i = Standardized test moving range at test order i. (For Sequence VID, $R_1 = 0$)

where: $Y_0=0$

The following is the control chart limit for the Shewhart chart for monitoring precision (R plotted against completion date order).

$0 + K$

K is a constant that determines the chart's estimated false detection rate. Deterioration in precision is signaled by control chart points exceeding the value of K. K is test type specific.

3. Exponentially Weighted Moving Average (EWMA) Chart for Monitoring Severity

The vertical axis of this control chart represents the EWMA of standardized calibration test results (Z). These results are plotted against completion date order (integer) which is on the horizontal axis. Z is calculated as follows:

Z_i = EWMA of the standardized test result at test order i.

Z_i = (LAMBDA) Y_i + (1 - LAMBDA) Z_{i-1}

where: $0 \leq \text{LAMBDA} \leq 1$,

$Z_0 = 0$ (For Sequence VIB, Z_0 = Mean Y_i of first two tests acceptable for Shewhart severity plus all operationally valid tests in between. For Sequence VID, Z_0 = Mean Y_i of the first three operationally valid tests.)

LAMBDA (λ) is the smoothing constant and must be between 0 and 1. This value determines the amount of weight given to the current and past data points. As LAMBDA decreases, past data points are given more weight and the resulting plot gets smoother. When LAMBDA is set equal to 1, the EWMA chart is equivalent to the Shewhart chart.

The following are the control chart limits for the EWMA chart for monitoring severity (Z plotted against completion date order).

$$0 \pm K\sqrt{\frac{\lambda}{2-\lambda}}$$

K is a constant that determines the chart's estimated false detection rate. K is test type specific.

4. EWMA Chart for Monitoring Precision

The vertical axis of this control chart represents the EWMA of standardized calibration test moving ranges (Q). These results are plotted against completion date order (integer) which is on the horizontal axis. Q is calculated as follows:

Q_i = (LAMBDA) R_i + (1 - LAMBDA) Q_{i-1}

where: $0 \leq \text{LAMBDA} \leq 1$, $Q_0 = 0$ (For Sequence VID, $Q_0 = 0$ and $Q_1 = 0$)

Q_i = EWMA of standardized test moving range results at test order i.

LAMBDA (λ) is the smoothing constant and must be between 0 and 1. The value Q at test order 0, Q_0, must be set equal to 0.

The following is the control chart limit for the EWMA chart for monitoring precision (Q plotted against completion date order).

$$0 \pm K\sqrt{\frac{\lambda}{2-\lambda}}$$

K is a constant that determines the chart's estimated false detection rate. K is test type specific.

5. Moving Standard Deviation (MSD) Chart for Monitoring Precision

The vertical axis of this control chart represents the four-test moving standard deviation of standardized calibration test results (N). These results are plotted against completion date order, which is on the horizontal axis. N is calculated as follows:

$$N_i = \sqrt{\frac{(Y_i - X)^2 + (Y_{i-1} - X)^2 + (Y_{i-2} - X)^2 + (Y_{i-3} - X)^2}{3}}$$

where: Y_i = Standardized test result at test order *i*.
$X = (Y_i + Y_{i-1} + Y_{i-2} + Y_{i-3})/4$

The following are the control chart limits for the MSD chart for monitoring precision (N plotted against completion date order):

+B1
+B2
+B3

where B1, B2, and B3 are constants that cover the expected range of test precision. All three constants are test-type specific.

EXHIBIT I: Example of Control Charts
Sequence IID Average Engine Rust Data

Completion Date Order	Reference Oil	Mean	Standard Deviation	T_i	Y_i	Z_i	R_i	Q_i
1	A	8.60	0.11	8.58	-0.182	-0.054	-1.304	-0.391
2	B	8.52	0.17	8.49	-0.177	-0.091	-2.154	-0.920
3	A	8.60	0.11	8.63	0.273	0.018	-0.718	-0.860
4	B	8.52	0.17	8.45	-0.412	-0.111	-0.341	-0.704
5	B	8.52	0.17	8.70	1.059	0.240	0.586	-0.317
6	A	8.60	0.11	8.51	-0.818	-0.077	0.964	0.067
7	B	8.52	0.17	8.55	0.176	-0.001	0.068	0.068
8	A	8.60	0.11	8.56	-0.364	-0.110	-0.563	-0.122
9	B	8.52	0.17	8.60	0.471	0.064	-0.134	-0.125
10	A	8.60	0.11	8.57	-0.273	-0.037	-0.257	-0.165
11	B	8.52	0.17	8.44	-0.471	-0.167	-1.260	-0.493
12	A	8.60	0.11	8.61	0.091	-0.090	-0.528	-0.504
13	B	8.52	0.17	8.56	0.235	0.008	-1.416	-0.777
14	A	8.60	0.11	8.60	0.000	0.005	-1.163	-0.893
15	B	8.52	0.17	8.42	-0.588	-0.173	-0.486	-0.771
16	A	8.60	0.11	8.68	0.727	0.097	0.428	-0.411
17	B	8.52	0.17	8.43	-0.529	-0.091	0.365	-0.178

Shewhart Chart for Monitoring Severity:	K=1.8		See Exhibit II
Shewhart Chart for Monitoring Precision:	K=1.46		See Exhibit III
EWMA Chart for Monitoring Severity:	K=1.8	LAMBDA=0.3	See Exhibit II
EWMA Chart for Monitoring Precision:	K=1.46	LAMBDA=0.3	See Exhibit III

Exhibit II:
Example Charts for Severity Data
Obtained from Exhibit I
Shewhart Chart: Yi vs Comp Date Order
EWMA: Zi vs Comp Date Order

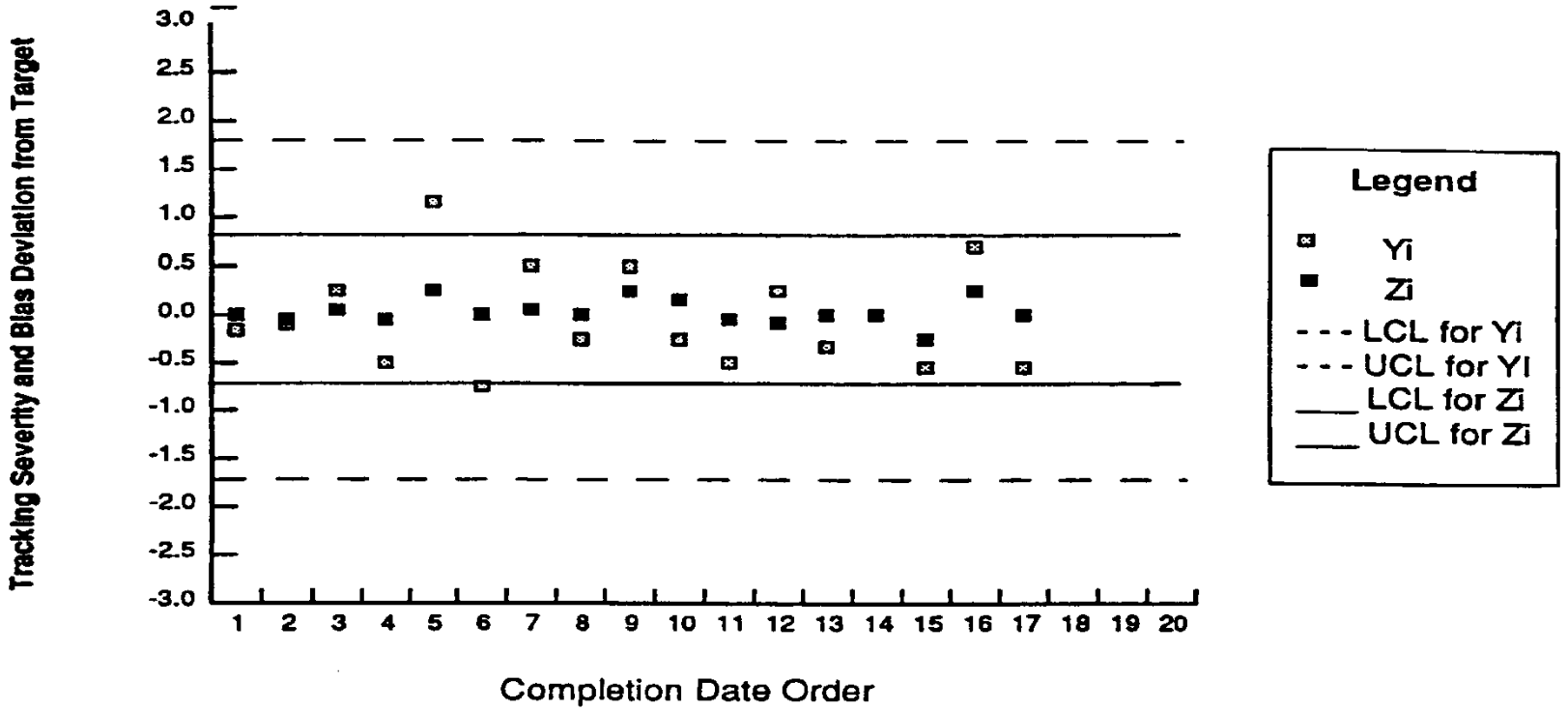
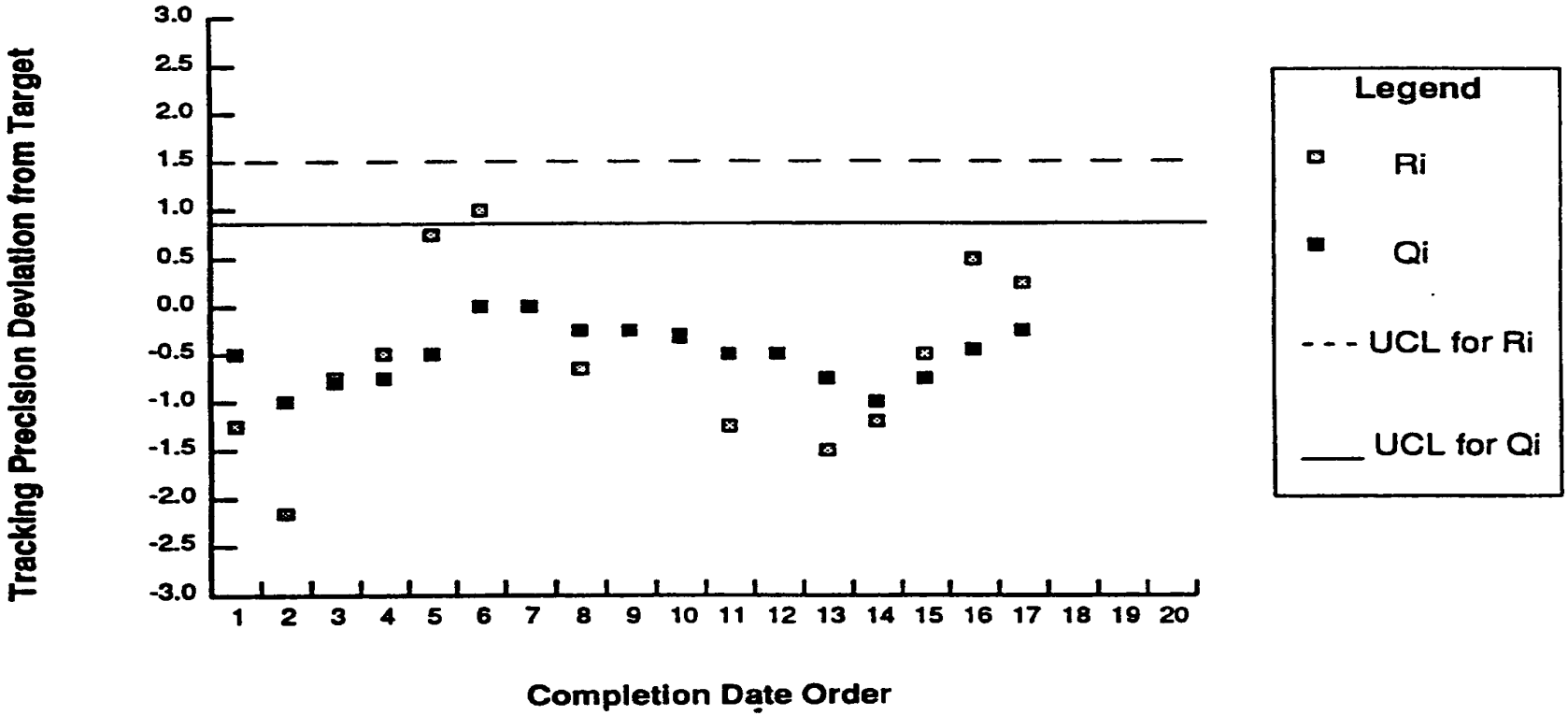


Exhibit III:
Example Charts for Precision Data
Obtained from Exhibit I

Shewhart Chart: Ri vs Comp Date Order

EWMA: Qi vs Comp Date Order



B. Engineering Judgment as Applied to the Interpretation of LTMS Control Charts

The Lubricant Test Monitoring System (LTMS) Shewhart, EWMA, and MSD control charts, by design, will infrequently produce false indications of the severity and/or precision of a test result. These false indications can occur at the stand, laboratory, and industry levels. One type of false indication is an alarm that is not the result of a real problem but is, rather, an anomaly. A second type of false indication occurs when a real problem exists, yet the control charts remain within acceptable limits. On occasion, when sufficient technical information is available, either type of false indication can be identified as such. In these cases, the ASTM Test Monitoring Center (TMC), through the application of engineering judgment, may determine that a deviation from normal LTMS actions is warranted. The following points describe the process by which engineering judgment is applied by the TMC:

1. The TMC determines if the potential exists for the application of engineering judgment in the interpretation of control charts.

2. When it is determined that the potential exists for the application of engineering judgment, all subsequent investigation proceeds under the assumption that the current control chart indications are correct.

3. When an engineering investigation is commenced, it is incumbent on the affected lab(s) to prepare necessary technical information in concert with the TMC.

4. The ACC Monitoring Agency will be notified that an engineering investigation involving control chart interpretation has commenced.

5. The TMC may solicit relevant input from outside sources, such as the Test Developer, Surveillance Panel Chairman, O&H Subpanel Leader and the ACC Monitoring Agency. In all cases, the confidentially of the affected lab(s) will be appropriately maintained.

6. If, in the judgment of the TMC, a deviation from normal LTMS actions is warranted, this judgment will be documented in writing along with a summary of the relevant technical information considered in making the judgment. The affected lab(s) and the ACC Monitoring Agency will receive copies of this document.

7. If, in the judgment of the TMC, normal LTMS action should be followed by the affected lab(s), no special documentation is required.

8. The application of engineering judgment in the interpretation of LTMS control charts is handled on a case-by-case basis. The TMC does not consider any prior judgment rendered to be precedent setting.

C. Guidelines for Numbering of New Test Stands

1. Each new test stand entering the LTMS shall be assigned a new stand number. If the new stand was previously calibrated in the LTMS, the original stand number plus a letter suffix (i.e., A, B, C, etc.) shall be used each time the stand reenters the system.

2. The TMC will use engineering judgment regarding the renumbering of test stands on which lapses in calibration periods occur. In such cases, a stand will generally not be renumbered if a calibration test sequence is started (and maintained) within one calibration period from the end of the previous period. However, if a review of the past and present configuration of the stand, tests conducted in between calibration periods (standardized or not), or any other pertinent information dictates, renumbering will be required. In cases where more than one calibration period has elapsed, generally, renumbering will be required.

D. TMC Notification Requirement

Effective November 1, 1994, testing laboratories shall notify the TMC whenever a test stand goes out of calibration for a reason other than exceeding the time limit published in the test procedure.

E. Surveillance Panel Guidelines for Revisions to the LTMS

1. The final authority for specifying the test-specific requirements of the LTMS resides with the surveillance panels of Subcommittee D02.B0.

2. Surveillance panels shall strive for unanimous approval of any revision to the LTMS.

3. Except in the case of an urgent target update, surveillance panel chairmen shall allow at least two weeks for review and possible panel discussion prior to the effective date of an LTMS revision.

4. To ensure the value of the two-week review, it is expected that each surveillance panel member will be responsible for representing their organization's technical position.

5. In those instances when the panel vote on a proposed LTMS revision is not unanimous, all minority voters shall be given sufficient opportunity to present the technical basis for their votes.

6. The surveillance panel shall make every effort to resolve minority voter concerns in order for there to be a consensus on the proposed LTMS revision. In the event unanimity cannot be achieved, a minority vote can be ruled non-persuasive by majority vote.

2. Sequence IIIF LTMS Requirements

The following are the specific Sequence IIIF calibration test requirements.

A. Reference Oils and Parameters

The critical parameters are Hours to 275% Viscosity Increase, Average Piston Varnish, Weighted Piston Deposits. The reference oils required for test stand and test laboratory calibration are reference oils accepted by the ASTM Sequence IIIF Surveillance Panel. The means and standard deviations for the current reference oils for each critical and noncritical parameter are presented below.

HOURS to 275% VISCOSITY INCREASE
Unit of Measure: Hours
CRITICAL PARAMETER

Reference Oil	Mean	Standard Deviation
433-1	121.09	7.701

AVERAGE PISTON VARNISH
Unit of Measure: Merits
CRITICAL PARAMETER

Reference Oil	Mean	Standard Deviation
433-1	9.30	0.300

WEIGHTED PISTON DEPOSITS
Unit of Measure: Merits
CRITICAL PARAMETER

Reference Oil	Mean	Standard Deviation
433-1	4.59	0.697

PERCENT VISCOSITY INCREASE @ 80 HOURS
Unit of Measure: 1/SQRT(VIS80)
NONCRITICAL PARAMETER

Reference Oil	Mean	Standard Deviation
433-1	0.1635099	0.0302263

PERCENT VISCOSITY INCREASE @ 60 HOURS
Unit of Measure: LN(VIS60)
NONCRITICAL PARAMETER

Reference Oil	Mean	Standard Deviation
433-1	3.55500	0.229905

B. Acceptance Criteria

1. New Test Stand

a. Less than six (6) Operationally Valid Calibration Results in Laboratory

- A minimum of two (2) operationally valid calibration tests, with no stand Shewhart severity alarms and no stand Shewhart precision alarms, must be conducted on any approved reference oils.

- 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.

b. Six (6) or more Operationally Valid Calibration Results in Laboratory*

- The first operationally valid test run on any approved reference oil must have no stand Shewhart severity alarm and no stand Shewhart precision alarm using the "Reduced K" values. If the first operationally valid calibration test does not meet these acceptance criteria, then the New Test Stand criteria listed above in 1.a must be followed.

* Only test results from calibrated stands in the laboratory count towards the tally of six (6) required operationally valid calibration tests. The sixth test must be complete (date and time) before the first test completes (date and time) on a new test stand that is seeking calibration with a single test result. In addition, the first test for the stand is to begin within six (6) months of the completion of the last acceptable calibration test. Also, there must not be any outstanding precision alarms for the laboratory.

2. Existing Test Stand

- The test stand must have previously been accepted into the system by meeting LTMS calibration requirements.

- 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.

- An existing Sequence IIIG test stand can be converted to an existing Sequence IIIF test stand by conducting one reference oil test, with no control chart alarms. The stand must have been previously calibrated as a Sequence IIIF stand and the reference oil test must

be completed within one year of the previous Sequence IIIF reference oil test on that stand.

3. Reference Oil Assignment

Once a test stand has been accepted into the system, the TMC will assign reference oils for continuing calibration according to the following reference oil mix:

- 100% of the scheduled calibration tests should be conducted on reference oil 433 or subsequent approved reblends.

4. Control Charts

In Section 1, the construction of the control charts that constitute the Lubricant Test Monitoring System is outlined. The constants used for the construction of the control charts for the Sequence IIIF, and the response necessary in the case of control chart limit alarms, are depicted below. Note that control charting all parameters, except Stuck Rings, is required.

LUBRICANT TEST MONITORING SYSTEM CONSTANTS

		EWMA				Shewhart Chart	
		LAMBDA		K		K	
Chart Level	Limit Type	Precision	Severity	Precision	Severity	Precision	Severity
Stand	Reduced K	--	--	--	--	1.70	1.48
	Action	0.3	0.3	2.00	2.24	2.00	1.80
Lab	Warning	0.3	--	2.00	--	--	--
	Action	0.3	0.2	2.72	1.96	2.00	1.80
Industry	Warning	0.2	0.2	2.00	2.24	--	--
	Action	0.2	0.2	2.65	2.88	--	--

The following are the steps that must be taken in the case of exceeding control chart limits. The steps are listed in order of priority, although charts should be studied simultaneously to determine the cause(s) of a problem. In the case of multiple alarms, contact the TMC for guidance. The laboratory always has the option of removing any engine from the system.

- Exceed EWMA laboratory chart action limit for precision (critical parameters only)
  - Cease all candidate starts in the laboratory. Develop plan to correct laboratory precision problem. Coordinate efforts with the TMC.
- Exceed EWMA laboratory chart warning limit for precision (critical parameters only)
  - Immediately begin two (2) calibration tests on calibrated test stands different from the test stand which exceeded the warning limit. (Calibration tests currently running on "existing" test stands may be used.) If a laboratory has two (2) test stands, conduct one (1) calibration test in each of those two (2) stands. If a laboratory has only one (1) test stand, conduct two (2) additional calibration tests in that test stand. Notify the TMC for potential laboratory visit. Candidate testing may continue on other calibrated test stands.

- Exceed EWMA test stand chart action limit for precision (critical parameters only)

  – Remove test stand from the system. Notify the TMC. Correct test stand precision problem. Follow requirements for entry of a new test stand into the system.

- Exceed Shewhart test stand chart action limit for precision (critical parameters only)

  – Conduct an additional calibration test.

- Exceed Shewhart laboratory chart action limit for precision (critical parameters only)

  – Notify TMC for guidance.

- Exceed EWMA laboratory chart action limit for severity (all parameters)

  – Calculate test laboratory Severity Adjustment (SA) for each parameter that exceeds the action limit. Use the current laboratory EWMA (Z_i) as follows:

HRS:	SA = $(-Z_i)$ x (7.701)
APV:	SA = $(-Z_i)$ x (0.220)
WPD:	SA = $(-Z_i)$ x (0.658)
VIS60:	SA =0.5* HRS SA

  – Confirm calculation with the TMC.

- Exceed EWMA test stand chart action limit for severity (critical parameters only)

  – Notify the TMC. If the direction of the test stand is deemed different from that of the laboratory, conduct an additional calibration test in the identified test stand. If this limit is still exceeded after the additional calibration test, then remove the test stand from the system, notify the TMC, correct test stand severity problem, and follow requirements for entry of a new test stand into the system.

- Exceed Shewhart test stand chart action limit for severity (critical parameters only)

  – Conduct an additional calibration test.

The following industry issues are handled by the TMC and do not require individual laboratory action.

- Exceed EWMA industry chart action limit (critical parameters only)
  - TMC to notify test developer, surveillance panel chairman, and ACC Monitoring Agency. Meeting of TMC, test developer, and surveillance panel required to determine course of action.
- Exceed EWMA industry chart warning limit (critical parameters only)
  - TMC to notify test developer, surveillance panel chairman, and ACC Monitoring Agency. Coordination of TMC, test developer, and surveillance panel chairman required to discuss potential problem.

3. Sequence IIIG LTMS Requirements

The following are the specific Sequence IIIG calibration test requirements.

A. Reference Oils and Critical Parameters

The parameters are Percent Viscosity Increase (PVIS), Weighted Piston Deposits (WPD), and Average Camshaft plus Lifter Wear (ACLW). The reference oils required for test stand and test laboratory calibration are reference oils accepted by the ASTM Sequence III Surveillance Panel. The means and standard deviations for the current reference oils for each parameter are presented below.

PERCENT VISCOSITY INCREASE
Unit of Measure: LN(PVIS)

Reference Oil	Mean	Standard Deviation
434	4.7269	0.3859
435	5.1838	0.3096
435-2	5.1838	0.3096
438	4.5706	0.1768

WEIGHTED PISTON DEPOSITS
Unit of Measure: Merits

Reference Oil	Mean	Standard Deviation
434	4.80	0.96
435	3.59	0.58
435-2	3.59	0.58
438	3.20	0.33

AVERAGE CAMSHAFT plus LIFTER WEAR
Unit of Measure: LN(ACLW)

Reference Oil	Mean	Standard Deviation
434	3.4657	0.1993
435	3.4985	0.2342
435-2	3.4985	0.2342
438	2.8814	0.2082

B. Acceptance Criteria

1. New Laboratory/Test Stand(s)

   a. A minimum of two (2) operationally valid calibration tests, with no Shewhart severity alarms (all parameters), are required to calibrate the laboratory.

   b. One (1) operationally valid calibration test, with no Shewhart severity alarms (all parameters), is required to calibrate a stand.

2. Existing Laboratory/Test Stand(s)

   a. On a stand rotational basis, a laboratory shall begin a reference oil test no later than 125 days following the completion of the laboratory's previous reference oil test or after no more than 25 test starts in the laboratory, whichever comes first. During periods following a failed stand calibration, invalid, or aborted test, a grace period of an additional 15 days or additional non-reference test starts equal to two (2) times the number of currently calibrated stands in the laboratory (as of EOT on failing stand), whichever comes first, shall be permitted from the completion date of the last acceptable calibration test. A laboratory has the option of moving to the next stand in the rotation to maintain lab calibration, independent of its action on the failing stand.

   b. The reference oil test interval listed in 2a shall be reduced if any stand calibration test exceeds certain limits of the Shewhart Chart for Severity (see below). During periods following a failed stand calibration test, the grace period described above in 2a shall apply.

   c. If a test stand fails two consecutive calibration tests on the same parameter but on different reference oils, the stand must generate two (2) operationally valid calibration tests, with no Shewhart severity alarms (all parameters).

   d. If not required to begin a reference oil test sooner, due to the above requirements, a stand shall begin a reference oil test no later than 365 days following the completion of the previous reference oil test on that stand.

3. Reference Oil Assignment:

   Of the two tests required to bring a new laboratory into the system, the first shall be conducted on reference oil 438 and the second on either reference oil 434 or 435. Once a test laboratory has been accepted into the system, 100% of the scheduled calibration tests should be conducted on reference oils 434, 435, and 438. If possible, the same oil should not be used for successive calibration tests in a stand.

4. Control Charts

   In Section 1, the construction of the control charts that constitute the Lubricant Test Monitoring System is outlined. The constants used for the construction of the control charts for the Sequence IIIG, and the response necessary in the case of control chart limit alarms, are depicted below. *Note that Sequence IIIG laboratory control charts are only updated following an acceptable stand calibration test*.

LUBRICANT TEST MONITORING SYSTEM CONSTANTS

		Severity			Precision	
		EWMA		Shewhart	EWMA	
Chart Level	Limit Type	LAMBDA	K	K	LAMBDA	K
Stand	Action	--	--	2.0 (3.0)[A]	--	--
Lab	Action	0.2	1.65	--	0.2	2.65
Industry	Warning	0.2	2.24	--	0.2	2.00
	Action	0.2	2.88	--	0.2	2.65

[A] 3.0 K-value applies in special cases; see alarm actions below

The following are the steps that must be taken in the case of exceeding control chart limits. The steps are listed in order of priority, although charts should be studied simultaneously to determine the cause(s) of a problem. In the case of multiple alarms, contact the TMC for guidance. The laboratory always has the option of removing any stand from the system.

- Exceed EWMA laboratory chart limit for severity
  - Calculate test laboratory Severity Adjustment (SA) for each parameter that exceeds the limit. Use the current laboratory EWMA (Z_i) as follows:

    PVIS: $SA = (-Z_i) \times (0.2919)$
    WPD: $SA = (-Z_i) \times (0.60)$
    ACLW: $SA = (-Z_i) \times (0.1903)$

  - Confirm calculation with the TMC.
- Exceed Shewhart stand chart limit for severity
  - If the test exceeds the Shewhart limit in the same direction (mild or severe) as an existing EWMA severity alarm, use the special case K-value and recheck the test for a Shewhart severity alarm. If the alarm no longer exists, no additional testing is required; however, the calibration period is reduced to 75 days or 18 test starts in the laboratory. If the test is still in alarm, conduct an additional calibration test on the same test stand. The additional calibration test must be started within 10 days or the stand is automatically removed from the system. For ACLW, tests failing outside the lower (mild) shewhart limit will not require an additional calibration test or a reduction in the calibration period.
  - If the test exceeds the Shewhart limit in the opposite direction (mild or severe) of an existing EWMA severity alarm or no EWMA severity alarm exists, conduct an additional calibration test on the same test stand. The additional calibration test must be started within 10 days or the stand is automatically removed from the system.

The following industry issues are handled by the TMC and do not require individual laboratory action.

- Exceed EWMA industry chart limits for severity
  - TMC to notify test developer, surveillance panel chairman, and ACC Monitoring Agency.
- Exceed EWMA industry chart limits for precision
  - TMC to notify test developer, surveillance panel chairman, and ACC Monitoring Agency

5. Removal of Test Stands from the System

   The laboratory must notify the TMC and the ACC Monitoring Agency when removing a stand from the system. No reference oil data shall be removed from the control charts from test stands that have been used for registered candidate oil testing. Reintroduction of a stand into the system requires completion of new stand acceptance requirements; however, previously calibrated stands that are removed from the system following a failed calibration test must generate two (2) operationally valid calibration tests, with no Shewhart severity alarms (all parameters). If a calibrated stand is removed from the system, or skipped in the laboratory stand rotation, and the laboratory wishes to bring the stand back into the system within 90 days of its removal, the surveillance panel shall be consulted. In all instances of stand removal, stand renumbering can occur only if the stand undergoes a significant rebuild, as agreed upon by the laboratory and the TMC.

6. Introduction of New Reference Oils

   When a new reference oil is introduced, Severity Adjustments shall not be calculated using results on a new reference oil until the test targets are based on at least eight (8) data points.

4. Sequence IIIGA LTMS Requirements

The following are the specific Sequence IIIGA calibration test requirements.

A. Reference Oils and Parameters

The critical parameter is MRV Apparent Viscosity. The reference oils required for test stand and test laboratory calibration are reference oils accepted by the ASTM Sequence III Surveillance Panel. The means and standard deviations for the current reference oils for the critical parameter are presented below.

MRV VISCOSITY
Unit of Measure: LN(MRV)

Reference Oil	Mean	Standard Deviation
434	10.7881	0.45550
435[A]	- -	- -
435-2[A]	- -	- -
438	9.8277	0.16646

[A] For oil 435 and 435-2, use Sequence IIIG PVIS Yi value as MRV Yi value

B. Acceptance Criteria

1. New Test Stand

   - Stand must be calibrated according to Sequence IIIG requirements. A Sequence IIIGA test must be conducted as part of each Sequence IIIG test.
   - A minimum of one (1) operationally valid calibration test must be conducted on any approved reference oil.
   - 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

   - Stand must be calibrated according to Sequence IIIG requirements. A Sequence IIIGA test must be conducted as part of each Sequence IIIG test.
   - The test stand must have been an ASTM TMC calibrated test stand prior to LTMS introduction or have previously been accepted into the system by meeting LTMS calibration requirements.
   - 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.

3. Control Charts

In Section 1 of the LTMS, the construction of the control charts that constitute the Lubricant Test Monitoring System is outlined. The constants used for the construction of the control charts for the Sequence IIIGA, and the response necessary in the case of control chart limit alarms, are depicted below.

LUBRICANT TEST MONITORING SYSTEM CONSTANTS

		Severity		
		EWMA		Shewhart
Chart Level	Limit Type	LAMBDA	K	K
Lab	Action	0.2	1.65	--
Industry	Warning	0.2	2.24	--
	Action	0.2	2.88	--

The following are the steps that must be taken in the case of exceeding control chart limits. The steps are listed in order of priority, although charts should be studied simultaneously to determine the cause(s) of a problem. In the case of multiple alarms, contact the TMC for guidance.

- Exceed EWMA laboratory chart action limit for severity
  - No action required

The following industry issues are handled by the TMC and do not require individual laboratory action.

- Exceed EWMA industry chart action limit
  - TMC to notify test developer, surveillance panel chairman, and ACC Monitoring Agency. Meeting of the TMC, test developer, and the surveillance panel required to determine course of action.
- Exceed EWMA industry chart warning limit
  - TMC to notify test developer, surveillance panel chairman, and ACC Monitoring Agency. Coordination of TMC, test developer, and surveillance panel chairman required to discuss potential problem.

5. Sequence IIIGB LTMS Requirements

The following are the specific Sequence IIIGB calibration test requirements.

A. Reference Oils and Parameters

The critical parameter is Phosphorus Retention. The reference oils required for test stand and test laboratory calibration are reference oils accepted by the ASTM Sequence III Surveillance Panel. The means and standard deviations for the current reference oils for the critical parameter are presented below.

PHOSPHORUS RETENTION
Unit of Measure: Percent

Reference Oil	Mean	Standard Deviation
434	76.00	2.02
434-1	76.00	2.02
435	82.40	2.28
435-2	82.40	2.28
438	78.20	2.56

B. Acceptance Criteria

1. New Test Stand

- Stand must be calibrated according to Sequence IIIG requirements. A Sequence IIIGB test must be conducted as part of each Sequence IIIG test.
- A minimum of one (1) operationally valid calibration test must be conducted on any approved reference oil.
- 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

- Stand must be calibrated according to Sequence IIIG requirements. A Sequence IIIGB test must be conducted as part of each Sequence IIIG test.
- The test stand must have been an ASTM TMC calibrated test stand prior to LTMS introduction or have previously been accepted into the system by meeting LTMS calibration requirements.
- 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.

3. Control Charts

In Section 1 of the LTMS, the construction of the control charts that constitute the Lubricant Test Monitoring System is outlined. The constants used for the construction of the control charts for the Sequence IIIGB, and the response necessary in the case of control chart limit alarms, are depicted below.

LUBRICANT TEST MONITORING SYSTEM CONSTANTS

		Severity		
		EWMA		Shewhart
Chart Level	Limit Type	LAMBDA	K	K
Lab	Action	0.2	1.65	--
Industry	Warning	0.2	2.24	--
	Action	0.2	2.88	--

The following are the steps that must be taken in the case of exceeding control chart limits. The steps are listed in order of priority, although charts should be studied simultaneously to determine the cause(s) of a problem. In the case of multiple alarms, contact the TMC for guidance.

- Exceed EWMA laboratory chart action limit for severity
  - Calculate test laboratory Severity Adjustment (SA) for each parameter that exceeds the limit. Use the current laboratory EWMA (Z_i) as follows:

    PHOS: $SA = (-Z_i) \times (2.33)$*

    * standard deviation based on RMSE of oils 434, 435 & 438

  - Confirm calculation with the TMC.

The following industry issues are handled by the TMC and do not require individual laboratory action.

- Exceed EWMA industry chart action limit
  - TMC to notify test developer, surveillance panel chairman, and ACC Monitoring Agency. Meeting of the TMC, test developer, and the surveillance panel required to determine course of action.
- Exceed EWMA industry chart warning limit
  - TMC to notify test developer, surveillance panel chairman, and ACC Monitoring Agency. Coordination of TMC, test developer, and surveillance panel chairman required to discuss potential problem.

6. Sequence IVA LTMS Requirements

A. Reference Oils and Parameters

The critical parameter is Average Camshaft Wear. The reference oils required for stand calibration are the reference oils accepted by the ASTM Sequence IVA Surveillance Panel. The means and standard deviations for the current reference oils for the critical parameter are presented below.

AVERAGE CAMSHAFT WEAR
Unit of Measure: micrometers

Reference Oil	Mean	Standard Deviation
1006-2	102.18	13.54
1007	84.76	15.40

B. Acceptance Criteria

1. New Test Stand

   a. Less than six (6) Operationally Valid Calibration Results in Laboratory

   - A minimum of two (2) operationally valid calibration tests, with no stand Shewhart severity alarms (all parameters) and no stand Shewhart precision alarms (critical parameters only) on any approved reference oils.

   - All operationally valid calibration results must be charted to determine if the test stand is currently "in control" as defined by the control chart from the Lubricant Test Monitoring System.

   b. Six (6) or more Operationally Valid Calibration Results in Laboratory*

   - The first operationally valid test run on any approved reference oil must have no stand Shewhart severity alarm and no stand Shewhart precision alarm using the "Reduced K" values. If the first operationally valid calibration test does not meet these acceptance criteria, then the New Test Stand criteria listed above in 1.a must be followed.

* Only test results from calibrated stands in the laboratory count towards the tally of six (6) required operationally valid calibration tests. The sixth test must complete (date and time) before the first test completes (date and time) on a new test stand that is seeking calibration with a single test result. In addition, the first test for the stand is to begin within six (6) months of the completion of the last acceptable calibration test. Also, there must not be any outstanding precision alarms for the laboratory.

2. Existing Test Stand

   The test stand must have previously been accepted into the system by meeting LTMS calibration requirements.

3. Reference Oil Assignment

   Once test stands have been accepted into the system, the TMC will assign reference oils for continuing calibration according to the following reference oil mix:

   - 100% of the scheduled calibration tests should be conducted on reference oils 1006 and 1007, or subsequent approved reblends.

4. Control Charts

   In Section 1, the construction of the control charts that constitute the Lubricant Test Monitoring System is outlined. The constants used for the construction of the control charts for Sequence IVA, and the response necessary in the case of control chart limit alarms, are depicted below. Note that control charting all parameters is required.

LUBRICANT TEST MONITORING SYSTEM CONSTANTS

		EWMA Chart				Shewhart Chart	
		LAMBDA		K		K	
Chart Level	Limit Type	Precision	Severity	Precision	Severity	Precision	Severity
Stand	Reduced K	--	--	--	--	1.11	1.48
	Action	0.3	0.3	1.46	1.80	1.46	1.80
Lab	Warning	0.2	--	1.46	--	--	--
	Action	0.2	0.3	2.33	1.80	1.46	1.80
Industry	Warning	0.2	0.2	1.46	1.80	--	--
	Action	0.2	0.2	2.33	2.58	--	--

The following are the steps that must be taken in the case of exceeding control chart limits. The steps are listed in order of priority, although charts should be studied simultaneously to determine the cause(s) of a problem. In the case of multiple alarms, contact the TMC for guidance.

- Exceed the EWMA laboratory chart action limit for precision

  – Cease all candidate starts in the laboratory. Develop plan to correct laboratory precision problem. Coordinate efforts with the TMC.

- Exceed EWMA laboratory chart warning limit for precision

  - Immediately begin two (2) calibration tests on calibrated test stands different from the test stand which exceeded the warning limit. (Calibration tests currently running on "existing" test stands may be used.) If a laboratory has two (2) test stands, conduct one (1) calibration test in each of those two (2) stands. If a laboratory has only one (1) test stand, conduct two (2) additional calibration tests in that test stand. Notify the TMC for potential laboratory visit. Candidate testing may continue on other calibrated test stands.

- Exceed EWMA test stand chart limit for precision

  - Remove test stand from the system. Notify the TMC. Correct test stand precision problem. Follow requirements for entry of a new test stand into the system.

- Exceed Shewhart test stand chart limit for precision

  - Conduct an additional calibration test.

- Exceed Shewhart laboratory chart limit for precision

  - Notify TMC for guidance.

- Exceed EWMA laboratory chart limit for severity

  - Calculate laboratory Severity Adjustment (SA) for each parameter that exceeds action limit, using the current laboratory EWMA (Z_i) as follows:

    ACW (μm) $\qquad SA = (-Z_i) * (14.87)$

  - Confirm calculations with TMC.

- Exceed EWMA test stand chart limit for severity

  - Notify the TMC. If the direction of the test stand is deemed different from that of the laboratory, conduct an additional calibration test in the identified test stand. If this limit is still exceeded after the additional calibration test, then remove the test stand from the system, notify the TMC, correct test stand severity problem, and follow requirements for entry of a new test stand into the system.

- Exceed Shewhart test stand chart limit for severity

  - Conduct an additional calibration test.

The following industry issues are handled by the TMC and do not require individual laboratory action.

- Exceed EWMA Industry chart action limit
  - TMC to notify test sponsor, surveillance panel chairman, and ACC Monitoring Agency. Meeting of TMC, test sponsor, and surveillance panel required to determine course of action.
- Exceed EWMA Industry chart warning limit
  - TMC to notify test sponsor, surveillance panel chairman, and ACC Monitoring Agency. Coordination of TMC, test sponsor, and surveillance panel chairman required to discuss potential problem.

7. Sequence VG LTMS Requirements

The following are the specific Sequence VG calibration test requirements.

A. Reference Oils and Parameters

The critical parameters are Average Engine Sludge, Average Rocker Cover Sludge, Average Engine Varnish, Average Piston Varnish, and Oil Screen Clogging. Number of Hot Stuck Rings is a discrete parameter and is monitored for occurrence only. The reference oils required for stand calibration are the reference oils accepted by the ASTM Sequence VG Surveillance Panel. The means and standard deviations for the current reference oils for each critical parameter are presented below.

AVERAGE ENGINE SLUDGE
Unit of Measure: Merits

Reference Oil	Mean	Standard Deviation
940	6.43	0.51
1006	8.43	0.60
1006-2	8.65	0.52
1007	8.93	0.30
1009	7.94	0.52

AVERAGE ROCKER COVER SLUDGE
Unit of Measure: Merits

Reference Oil	Mean	Standard Deviation
940	8.15	0.92
1006	9.35	0.20
1006-2	9.40	0.34
1007	8.99	0.41
1009	9.29	0.27

AVERAGE ENGINE VARNISH
Unit of Measure: Merits

Reference Oil	Mean	Standard Deviation
940	8.79	0.25
1006	9.27	0.10
1006-2	9.24	0.22
1007	9.24	0.11
1009	8.99	0.22

AVERAGE PISTON VARNISH
Unit of Measure: Merits

Reference Oil	Mean	Standard Deviation
940	7.20	0.63
1006	8.49	0.18
1006-2	8.52	0.43
1007	8.57	0.23
1009	7.79	0.43

OIL SCREEN CLOGGING
Unit of Measure: LN(OSCRNSLG + 1)

Reference Oil	Mean	Standard Deviation
940	3.951	0.840
1006	1.384	0.850
1006-2	0.896	1.038
1007	0.968	0.614
1009	2.200	1.038

NUMBER OF HOT STUCK RINGS
Unit of Measure: Count

Reference Oil	Maximum Allowable
940	0
1006	0
1006-2	0
1007	0
1009	0

B. Acceptance Criteria

1. New Test Stand

a. Less than six (6) Operationally Valid Calibration Results in Laboratory

- A minimum of two (2) operationally valid calibration tests, with no stand Shewhart severity alarms and no stand Shewhart precision alarms must be conducted on any approved reference oils except 940.

- All operationally valid calibration results must be charted to determine if the test stand is currently "in control" as defined by the control chart from the Lubricant Test Monitoring System.

b. Six (6) or more Operationally Valid Calibration Results in Laboratory*

- The first operationally valid test run on any approved reference oil must have no stand Shewhart severity alarm and no stand Shewhart precision alarm using the "Reduced K" values. If the first operationally valid calibration test does not meet this acceptance criteria, then the New Test Stand criteria listed above in 1.a must be followed.

* Only test results from calibrated stands in the laboratory count towards the tally of six (6) required operationally valid calibration tests. The sixth test must complete (date and time) before the first test completes (date and time) on a new test stand that is seeking calibration with a single test result. In addition, the first test for the stand is to begin within six (6) months of the completion of the last acceptable calibration test. Also, there must not be any outstanding precision alarms for the laboratory.

2. Existing Test Stand

- The test stand must have previously been accepted into the system by meeting LTMS calibration requirements.

3. Reference Oil Assignment

Once test stands have been accepted into the system, the TMC will assign reference oils for continuing calibration according to the following reference oil mix:

- 25% each, oils 940, 1006, 1007, and 1009 (or subsequent reblends).

4. Control Charts

In Section 1, the construction of the control charts that constitute the Lubricant Test Monitoring System is outlined. The constants used for the construction of the control charts for Sequence VG, and the response necessary in the case of control chart limit alarms, are depicted below. Note that control charting all parameters, except Number of Hot Stuck Rings, is required.

LUBRICANT TEST MONITORING SYSTEM CONSTANTS

		EWMA Chart				Shewhart Chart	
		LAMBDA		K		K	
Chart Level	Limit Type	Precision	Severity	Precision	Severity	Precision	Severity
Stand	Reduced K	--	--	--	--	1.48	1.48
	Action	0.30	0.30	1.80	2.10	1.80	1.80
Lab	Warning	0.30	-	1.80	-	-	-
	Action	0.30	0.20	2.24	1.96	1.80	1.80
Industry	Warning	0.15	0.15	1.80	2.10	-	-
	Action	0.15	0.15	2.57	2.81	2.00	2.00

The following are the steps that must be taken in the case of exceeding control chart limits. The steps are listed in order of priority, although charts should be studied simultaneously to

determine the cause(s) of a problem. In the case of multiple alarms, contact the TMC for guidance.

- Exceed the EWMA laboratory chart action limit for precision (excludes Oil Screen Clogging)

  – Cease all candidate starts in the laboratory. Develop plan to correct laboratory precision problem. Coordinate efforts with the TMC.

- Exceed EWMA laboratory chart warning limit for precision (excludes Oil Screen Clogging)

  – Immediately begin two (2) calibration tests on calibrated test stands different from the test stand which exceeded the warning limit. (Calibration tests currently running on "existing" test stands may be used.) If a laboratory has two (2) test stands, conduct one (1) calibration test in each of those two (2) stands. If a laboratory has only one (1) test stand, conduct two (2) additional calibration tests in that test stand. Notify the TMC for potential laboratory visit. Candidate testing may continue on other calibrated test stands.

- Exceed EWMA test stand chart limit for precision (excludes Oil Screen Clogging)

  – Remove test stand from the system. Notify the TMC. Correct test stand precision problem. Follow requirements for entry of a new test stand into the system.

- Exceed Shewhart test stand chart limit for precision (excludes Oil Screen Clogging)

  – Conduct an additional calibration test.

- Exceed Shewhart laboratory chart limit for precision (excludes Oil Screen Clogging)

  – Notify TMC for guidance.

- Exceed EWMA laboratory chart limit for severity

  – Calculate laboratory Severity Adjustment (SA) for each parameter that exceeds action limit, using the current laboratory EWMA (Z_i) as follows:

AES:	$SA=(-Z_i) \times (0.45)$*
RCS:	$SA=(-Z_i) \times (0.56)$*
AEV:	$SA=(-Z_i) \times (0.16)$*
APV:	$SA=(-Z_i) \times (0.31)$*
OSCRNSLG (Transformed Scale):	$SA=(-Z_i) \times (0.793)$*

  * Pooled s based on reference oils 1006, 1006-2, 1007, and 1009

  – Confirm calculations with TMC

- Exceed EWMA test stand chart limit for severity

  - Notify the TMC. If the direction of the test stand is deemed different from that of the laboratory, conduct an additional calibration test in the identified test stand. If this limit is still exceeded after the additional calibration test, then remove the test stand from the system, notify the TMC, correct test stand severity problem, and follow requirements for entry of a new test stand into the system.

- Exceed Shewhart test stand chart limit for severity

  - Conduct an additional calibration test.

The following industry issues are handled by the TMC and do not require individual laboratory action.

- Exceed EWMA Industry chart action limit

  - TMC to notify test sponsor, surveillance panel chairman, and ACC Monitoring Agency. Meeting of TMC, test sponsor, and surveillance panel required to determine course of action.

- Exceed EWMA Industry chart warning limit

  - TMC to notify test sponsor, surveillance panel chairman, and ACC Monitoring Agency. Coordination of TMC, test sponsor, and surveillance panel chairman required to discuss potential problem.

8. Sequence VIB LTMS Requirements

The following are the specific Sequence VIB calibration test requirements.

A. Reference Oils and Critical Parameters

The critical parameters are Fuel Economy Improvement for oil at 16 hours of aging (FEI1) and Fuel Economy Improvement for aged oil at 96 hours (FEI2). The reference oils required for test stand/engine combination and test laboratory calibration are reference oils accepted by the ASTM Sequence VIB Surveillance Panel. The means and standard deviations for the current reference oils for the critical parameter are presented below.

FUEL ECONOMY IMPROVEMENT at 16 Hours
Unit of Measure: Percent FEI1

Reference Oil	Mean	Standard Deviation
538	1.89	0.22
538-1	2.02	0.22
539	0.91	0.22
1006	1.40	0.22
1008	1.88	0.22
1008-1	1.96	0.22

FUEL ECONOMY IMPROVEMENT at 96 Hours
Unit of Measure: Percent FEI2

Reference Oil	Mean	Standard Deviation
538	1.55	0.21
538-1	1.47	0.21
539	0.43	0.21
1006	0.50	0.21
1008	1.27	0.21
1008-1	1.30	0.21

B. Acceptance Criteria

1. New Test Stand/Engine

- A minimum of two (2) operationally valid calibration tests (uninterrupted by non-reference oil tests) with no stand/engine Shewhart severity alarms and no alarms after the last reference oil test prior to non-reference oil testing is required. These tests must be conducted on reference oil 538, 539, 1006, or 1008 or subsequent approved reblends. The first two tests must be run using different reference oils.

- Test results from stand/engines that fail to meet new stand/engine calibration requirements where the engine is considered "abandoned" are not charted. Tests unacceptable for Shewhart severity run prior to the first acceptable test for Shewhart severity are not charted. All other operationally valid calibration test results must be charted to determine if the test stand/engine is currently "in control" as defined by the control charts from the Lubricant Test Monitoring System.

2. Existing Test Stand/Engine

   - The test stand/engine must have previously been accepted into the system by meeting LTMS calibration requirements.

   - All operationally valid calibration test results, except as noted in B.1 above, must be charted to determine if the test stand/engine is currently "in control" as defined by the control charts from the Lubricant Test Monitoring System.

3. Reference Oil Assignment

   Once a test stand/engine has been accepted into the system, the TMC will assign reference oils for continuing calibration according to the following reference oil mix:

   - 50% of the scheduled calibration tests should be conducted on reference oils 538, or subsequent approved reblends.

   - 50% of the scheduled calibration tests should be conducted on reference oil 1008, or subsequent approved reblends.

4. Control Charts

   In Section 1, the construction of the control charts that constitute the Lubricant Test Monitoring System is outlined. The constants used for the construction of the control charts for the Sequence VIB, and the response necessary in the case of control chart limit alarms, are depicted below.

LUBRICANT TEST MONITORING SYSTEM CONSTANTS

		EWMA				Shewhart Chart	
		LAMBDA		K		K	
Chart Level	Limit Type	Precision	Severity	Precision	Severity	Precision	Severity
Stand/Engine	Warning	0.30	0.30	1.80	--	--	--
	Action	0.30	0.30	2.58	0.00	1.80	1.96
Industry	Warning	0.15	0.15	1.80	2.10	--	--
	Action	0.15	0.15	2.58	2.81	--	--

The following are the steps that must be taken in the case of exceeding control chart limits. The steps are listed in order of priority, although charts should be studied simultaneously to determine the cause(s) of a problem. In the case of multiple alarms, contact the TMC for guidance. The laboratory always has the option of removing any engine from the system.

- Exceed EWMA test stand/engine chart action limit for precision

  - Remove test stand/engine combination from the system. Notify the TMC. Correct test stand/engine precision problem. Follow requirements for entry of a new test stand/engine into the system. Control chart status (continue/restart) is to be determined by the TMC. Candidate testing may continue on other calibrated test stand/engine combinations in the laboratory.

- Exceed EWMA test stand/engine chart warning limit for precision

  - Immediately begin two (2) consecutive calibration tests on the stand/engine combination which exceeded the warning limit. Notify the TMC. Candidate testing may continue on other calibrated test stand/engine combinations in that laboratory.

- Exceed Shewhart test stand/engine chart action limit for precision

  - Conduct an additional calibration test on the stand/engine combination which exceeded the action limit.

- Exceed EWMA test stand/engine chart action limit for severity

  - Calculate test stand/engine Severity Adjustment (SA) for each parameter using the current test stand/engine EWMA (Z_i) as follows:

    FEI1: $SA = (-Z_i) \times (0.22)$
    FEI2: $SA = (-Z_i) \times (0.21)$

  - Confirm calculation with the TMC.

- Exceed Shewhart test stand/engine chart action limit for severity

  - Conduct an additional calibration test on the stand/engine combination, which exceeded the action limit.

The following industry issues are handled by the TMC and do not require individual laboratory action.

- Exceed EWMA industry chart action limit

  - TMC to notify test developer, surveillance panel chairman, and ACC Monitoring Agency. Meeting of TMC, test developer, and surveillance panel required to determine course of action.

- Exceed EWMA industry chart warning limit

  - TMC to notify test developer, surveillance panel chairman, and ACC Monitoring Agency. Coordination of TMC, test developer, and surveillance panel chairman required to discuss potential problem.

9. Sequence VID LTMS Requirements

The following are the specific Sequence VID calibration test requirements.

A. Reference Oils and Critical Parameters

The critical parameters are Fuel Economy Improvement at 16 hours (FEI1) and Fuel Economy Improvement at 100 hours (FEI2). The reference oils required for test stand/engine calibration are reference oils accepted by the ASTM Sequence VI Surveillance Panel. The means and standard deviations for the current reference oils for each critical parameter are presented below.

FUEL ECONOMY IMPROVEMENT at 16 Hours
Unit of Measure: Percent

Reference Oil	Mean	Standard Deviation
540 (GF5A)	1.32	0.12
541 (GF5D)	0.87	0.12
542 (GF5X)	1.49	0.12
1010	1.34	0.12

FUEL ECONOMY IMPROVEMENT at 100 Hours
Unit of Measure: Percent

Reference Oil	Mean	Standard Deviation
540 (GF5A)	1.04	0.14
541 (GF5D)	0.71	0.14
542 (GF5X)	0.80	0.14
1010	1.10	0.18

B. Acceptance Criteria

1. New Test Stand/Engine

   a. A minimum of three (3) operationally valid calibration tests (uninterrupted by non-reference oil tests), with no Shewhart severity alarms (all parameters), are required to calibrate each stand/engine. Precision requirements and severity adjustments are only to be evaluated after the third operationally valid test that has successfully met the Shewhart severity requirement. Note that Special K limits may not be used for Shewhart severity control charts in the calibration of a new stand/engine. Special K limits may only be used for existing stand/engines.

   b. For every two (2) operationally invalid tests during the attempt to calibrate a new stand/engine after the first operationally valid test (the count does not start until after the first valid test), an additional operationally valid calibration test will be added to the stand/engine calibration requirement.

c. The first (3) tests must be conducted on reference oils 542 (GF5X), 541 (GF5D) and 1010, in that order for new engine reference acceptance.

2. Existing Test Stand/Engine

a. The stand/engine must have previously been accepted into the system by meeting the LTMS requirements

b. All operationally valid tests must be charted to determine if the stand/engine is in control as defined by the control charts in the Lubricant Test Monitoring System. If there are two (2) or more operationally invalid tests during the attempt to calibrate an existing stand/engine, then two (2) operationally valid calibration tests, with no Shewhart severity alarms (all parameters), are required to calibrate the stand/engine.

3. Reference Oil Assignment:

a. For new stand/engines, see Section 1.c above.

b. Once a stand/engine has been accepted into the system, 100% of the scheduled calibration tests should be conducted on reference oils 540, 542, and 1010 or subsequent approved reblends. If possible, the same oil should not be used for successive calibration tests in a stand.

4. Control Charts

In Section 1, the construction of the control charts that contribute to the Lubricant Test Monitoring System is outlined. The constants used for the construction of the control charts for the VID, and the response necessary in the case of control chart limit alarms, are depicted below. *Note that laboratory control charts are only updated following an acceptable stand/engine calibration test*.

LUBRICANT TEST MONITORING SYSTEM CONSTANTS

		EWMA Chart				Shewhart Chart	
		LAMBDA		K		K	
Chart Level	Limit Type	Precision	Severity	Precision	Severity	Precision	Severity
Stand/Engine	Special K	--	--	--	--	--	2.96
	Warning	--	--	--	--	1.645	
	Action	0.1	0.3	1.645	0.000	2.325	1.96
Industry	Warning	0.1	0.2	1.645	1.96	--	--
	Action	0.1	0.2	2.33	2.575	--	--

The following are the steps that must be taken in the case of exceeding control chart limits. The steps are listed in order of priority, although charts should be studied simultaneously to determine the cause(s) of a problem. In the case of multiple alarms, contact the TMC for guidance, but note that except for severity adjustments (enacting a severity adjustment may occur at the same time as an action for a different alarm), the actions for alarms are not cumulative (in other words, only the most severe action is required in the case of multiple alarms in addition to a possible severity adjustment). The laboratory always has the option of removing any stand and/or engine from the system.

- Exceed EWMA stand/engine action limit for precision
  - Special K no longer applies for the parameter.
  - Immediately conduct one additional calibration test in the offending stand/engine with no Shewhart severity alarms (all parameters). Precision requirements are waived until the next reference test.
  - Reduce the reference interval for the next scheduled reference test in the stand/engine by fifty percent (50%).
- Exceed Shewhart stand/engine action limit for precision
  - Special K no longer applies for the parameter.
  - Reduce the reference interval for the next scheduled reference test in the stand/engine by fifty percent (50%).
- Exceed Shewhart stand/engine warning limit for precision
  - Special K no longer applies for the parameter.
  - Reduce the reference interval for the next scheduled reference test in the stand/engine by twenty-five percent (25%). (round down)
- Exceed Shewhart stand/engine action limit for severity
  - First check the status of the precision alarms. Under certain circumstances, Special K may not be utilized.
  - Immediately conduct an additional calibration test in the offending stand/engine. However, if a EWMA severity action alarm existed in the stand/engine prior to the reference test, and the alarm is in the direction of the EWMA severity action alarm, then an additional calibration test need not be run as long as the test result is within the Special K control chart limit.
  - If there are two (2) or more operationally invalid tests during the attempt to calibrate an existing stand/engine, then two (2) operationally valid calibration tests, with no Shewhart severity alarms (all parameters), are required to calibrate the stand/engine.

- Exceed EWMA stand/engine action limit for severity

  - First check the status of the precision alarms. Under certain circumstances, Special K may not be utilized.

  - Calculate stand/engine Severity Adjustment (SA) for each parameter that exceeds the action limit. Use the current laboratory EWMA (Zi) as follows:

    FEI1: $SA = (-Z_i) \times (0.12)$
    FEI2: $SA = (-Z_i) \times (0.14)$

  - Confirm calculation with the TMC.

The following industry issues are handled by the TMC and do not require individual laboratory action.

- Exceed EWMA industry chart action limit

  - TMC to notify test developer, surveillance panel chairman, and ACC Monitoring Agency. Meeting of TMC, test developer, and surveillance panel required to determine course of action.

- Exceed EWMA industry chart warning limit

  - TMC to notify test developer, surveillance panel chairman, and ACC Monitoring Agency. Coordination of TMC, test developer, and surveillance panel chairman required to discuss potential problem.

5. Removal of Test Stand/Engines from the System

The laboratory must notify the TMC and the ACC Monitoring Agency when removing a stand/engine from the system. No reference oil data shall be removed from the control charts from test stand/engines that have been used for registered candidate oil testing. Reintroduction of a stand/engine into the system requires completion of new stand/engine acceptance requirements. In all instances of stand/engine removal, stand/engine renumbering can occur only if the stand/engine undergoes a significant rebuild, as agreed upon by the laboratory and the TMC.

10. Sequence VIII LTMS Requirements

The following are the specific Sequence VIII calibration test requirements. For purposes of the Sequence VIII, a test stand is defined as an engine/stand combination.

A. Reference Oils and Parameters

The critical parameter is Total Bearing Weight Loss (TBWL). The reference oils required for test stand and laboratory calibration are reference oils accepted by the ASTM Sequence VIII Surveillance Panel. The means and standard deviations for the current reference oils for the critical parameter are presented below.

TOTAL BEARING WEIGHT LOSS
Unit of Measure: mg
CRITICAL PARAMETER

Reference Oil	Mean	Standard Deviation
704-1	8.3	2.32
1006	15.9	4.85
1006-2	17.5	4.23
1009	13.8	2.14

10-HOUR STRIPPED VISCOSITY
Unit of Measure: centistokes
NONCRITICAL PARAMETER

Reference Oil	Mean	Standard Deviation
704-1	10.27	0.11
1006	9.00	0.17
1006-2	9.37	0.07
1009	9.51	0.10

B. Acceptance Criteria

In addition to the calibration test requirements described below for new and existing test stands:

- A new bearing batch requires a minimum of two (2) operationally valid calibration tests with no stand Shewhart alarms per laboratory.

1. New Test Stand

   a. Less than six (6) Operationally Valid Calibration Results in Laboratory

      - A minimum of two (2) operationally valid calibration tests, with no stand Shewhart severity or precision alarms, must be conducted using the same bearing batch/lot combination on reference oils 704, and/or 1006, or subsequent approved reblends.

      - 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.

   b. Six (6) or more Operationally Valid Calibration Results in Laboratory*

      - The first operationally valid calibration test run on any approved reference oil must have no stand Shewhart severity alarm and no stand Shewhart precision alarm using the "Reduced K" values. If the first operationally valid calibration test does not meet this acceptance criteria, then the New Test Stand criteria listed above in 1.a must be followed.

   * Only test results from calibrated stands in the laboratory count towards the tally of six (6) required operationally valid calibration tests. The sixth test must complete (date and time) before the first test completes (date and time) on a New Test Stand that is seeking calibration with a single test result. In addition, the first test for the stand is to begin within six (6) months of the completion of the last acceptable calibration test. Also, there must not be any outstanding precision alarms for the laboratory.

2. Existing Test Stand

   - The test stand must have previously been accepted into the system by meeting LTMS calibration requirements.

3. Reference Oil Assignment

   Once test stands have been accepted into the system, the TMC will assign reference oils for continuing calibration according to the following reference oil mix:

   - 100% of the scheduled calibration tests should be conducted on reference oils 704, 1006, and 1009, or subsequent approved reblends.

4. Control Charts

   In Section 1, the construction of the control charts that constitute the Lubricant Test Monitoring System is outlined. The constants used for the construction of the control charts for the Sequence VIII, and the response necessary in the case of control chart limit alarms, are depicted below.

LUBRICANT TEST MONITORING SYSTEM CONSTANTS

		EWMA Chart				Shewhart Chart	
		LAMBDA		K		K	
Chart Level	Limit Type	Precision	Severity	Precision	Severity	Precision	Severity
Stand	Reduced K	--	--	--	--	1.31	1.66
	Action	0.3	0.3	1.46	1.80	1.64	1.96
Lab	Warning	0.3	--	1.46	--	--	--
	Action	0.3	0.2	2.33	1.80	1.64	1.96
Industry	Warning	0.2	0.2	1.46	1.80	--	--
	Action	0.2	0.2	2.33	2.58	--	--

The following are the steps that must be taken in the case of exceeding control chart limits. The steps are listed in order of priority, although charts should be studied simultaneously to determine the cause(s) of a problem. In the case of multiple alarms, contact the TMC for guidance.

- Exceed EWMA laboratory chart action limit for precision (critical parameter only)
  - Cease all candidate test starts in the laboratory. Develop plan to correct laboratory precision problem. Coordinate efforts with the TMC.
- Exceed EWMA laboratory chart warning limit for precision (critical parameter only)
  - Immediately begin two (2) calibration tests on calibrated test stands different from the test stand which exceeded the warning limit. (Calibration tests currently running on "existing" test stands may be used.) If a laboratory has two (2) test stands, conduct one (1) calibration test in each of those two (2) stands. If a laboratory has only one (1) test stand, conduct the two (2) additional calibration tests in that test stand. Notify the TMC for potential laboratory visit. Candidate testing may continue on other calibrated test stands.
- Exceed EWMA test stand chart limit for precision (critical parameter only)
  - Remove test stand from the system. Notify the TMC. Correct test stand precision problem. Follow requirements for entry of a new test stand into the system.
- Exceed Shewhart test stand chart limit for precision
  - Conduct an additional calibration test.
- Exceed Shewhart laboratory chart action limit for precision
  - Notify the TMC for guidance.

- Exceed EWMA laboratory chart action limit for severity (critical parameter only)

  - Calculate laboratory Severity Adjustment (SA) for TBWL, using the current laboratory EWMA (Z_i) as follows:

    TBWL: $SA = (-Z_i) \times (4.80)$

  - Confirm calculations with the TMC.

- Exceed EWMA test stand chart limit for severity (critical parameter only)

  - Notify the TMC. If the direction of the test stand severity is deemed different from that of the test laboratory, conduct an additional calibration test in the identified test stand. If this limit is still exceeded after the additional calibration test, then remove test stand from the system, notify the TMC, correct test stand severity problem, and follow requirements for entry of a new test stand into the system.

- Exceed Shewhart test stand chart limit for severity

  - Conduct an additional calibration test.

The following Industry issues are handled by the TMC and do not require individual laboratory action.

- Exceed EWMA industry chart action limit (critical parameter only)

  - TMC to notify test sponsor, surveillance panel chairman, and ACC Monitoring Agency. Meeting of TMC, parts supplier, and surveillance panel required to determine course of action.

- Exceed EWMA industry chart warning limit (critical parameter only)

  - TMC to notify test sponsor, surveillance panel chairman, and ACC Monitoring Agency. Coordination of TMC, parts supplier, and surveillance panel chairman required to discuss potential problem.

11. 1M-PC LTMS Requirements

The following are the specific 1M-PC calibration test requirements.

A. Reference Oils and Critical Parameters

The critical parameters are Weighted Total Demerits and Top Groove Fill. The reference oils required for test stand and test laboratory calibration are reference oils accepted by the ASTM Single Cylinder Diesel Surveillance Panel. The means and standard deviations for the current reference oils for each critical parameter are presented below.

WEIGHTED TOTAL DEMERITS
Unit of Measure: Demerits

Reference Oil	Mean	Standard Deviation
873-1	232.5	50.5
873-2	232.5	50.5

TOP GROOVE FILL
Unit of Measure: Percent

Reference Oil	Mean	Standard Deviation
873-1	41.0	16.1
873-2	41.0	16.1

B. Acceptance Criteria

1. New Test Stand

   a. Less than six (6) Operationally Valid Calibration Results in Laboratory

   - A minimum of two (2) operationally valid calibration tests, with no stand Shewhart severity alarms and no stand Shewhart precision alarms, must be conducted on any approved reference oils.

   - 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.

   b. Six (6) or more Operationally Valid Calibration Results in Laboratory *

   - The first operationally valid calibration test run on any approved reference oil must have no stand Shewhart severity alarm and no stand Shewhart precision alarm using the "Reduced K" values. If the first operationally valid calibration test does not meet this acceptance criteria, then the New Test Stand criteria listed above in 1.a must be followed.

* Only test results from calibrated stands in the laboratory count towards the tally of six (6) required operationally valid calibration tests. The sixth test must complete (date and time) before the first test completes (date and time) on a New Test Stand that is seeking calibration with a single test result. In addition, the first test for the stand is to begin within six (6) months of the completion of the last acceptable calibration test. Also, there must not be any outstanding precision alarms for the laboratory.

2. Existing Test Stand

- The test stand must have been TMC calibrated prior to LTMS introduction or previously accepted into the system by meeting LTMS calibration requirements.

- All operationally valid calibration test results on reference oil 873 and subsequent approved reblends 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.

3. Reference Oil Assignment

Once test stands have been accepted into the system, the TMC will assign reference oils for continuing calibration according to the reference oil mix:

- 100% of the scheduled calibration tests should be conducted on reference oil 873 or subsequent approved reblends.

4. Control Charts

In Section 1, the construction of the control charts that constitute the Lubricant Test Monitoring System is outlined. The constants used for the construction of the control charts for the 1M-PC, and the response necessary in the case of control chart limit alarms, are depicted below. Note that control charting all parameters is required.

LUBRICANT TEST MONITORING SYSTEM CONSTANTS

		EWMA Chart				Shewhart Chart	
		LAMBDA		K		K	
Chart Level	Limit Type	Precision	Severity	Precision	Severity	Precision	Severity
Stand	Reduced K	--	--	--	--	1.48	1.43
	Action	0.3	0.3	1.74	2.05	1.74	2.00
Lab	Warning	0.2	--	1.74	--	--	--
	Action	0.2	0.2	2.58	1.96	1.74	2.00
Industry	Warning	0.2	0.2	1.74	2.05	--	--
	Action	0.2	0.2	2.58	2.81	--	--

The following are the steps that must be taken in the case of exceeding control chart limits. The steps are listed in order of priority, although charts should be studied simultaneously to determine the cause(s) of a problem. In the case of multiple alarms, contact the TMC for guidance.

- Exceed EWMA laboratory chart action limit for precision

  – Immediately provide written notice of the alarm and its meaning to all Test Purchasers and the TMC. This notice shall be appended to all test reports during the alarm period.

- Exceed EWMA laboratory chart warning limit for precision

  – Immediately provide written notice of the alarm and its meaning to all Test Purchasers and the TMC. This notice shall be appended to all test reports during the alarm period.

- Exceed EWMA test stand chart limit for precision

  – Immediately provide written notice of the alarm and its meaning to all Test Purchasers and the TMC. This notice shall be appended to all test reports for the stand in question during the alarm period.

- Exceed Shewhart test stand chart limit for precision

  – Immediately provide written notice of the alarm and its meaning to all Test Purchasers and the TMC. This notice shall be appended to all test reports for the stand in question during the alarm period.

- Exceed Shewhart laboratory chart action limit for precision

  – Immediately provide written notice of the alarm and its meaning to all Test Purchasers and the TMC. This notice shall be appended to all test reports during the alarm period.

- Exceed EWMA laboratory chart action limit for severity

  – Calculate laboratory Severity Adjustment (SA) for each parameter that exceeds action limit, using the current laboratory EWMA (Z_i) as follows:

Weighted Total Demerits:	$SA = (-Z_i) \times (50.5)$
Top Groove Fill:	$SA = (-Z_i) \times (16.1)$

  – Confirm calculations with the TMC.

- Exceed EWMA test stand chart limit for severity

  – Notify the TMC. If the direction of the test stand severity is deemed different from that of the test laboratory, conduct an additional calibration test in the identified test stand. If this limit is still exceeded after the additional calibration test, then remove test stand from the system, notify the TMC, correct test stand severity problem, and follow requirements for entry of a new test stand into the system.

- Exceed Shewhart test stand chart limit for severity

  - Conduct an additional calibration test.

The following industry issues are handled by the TMC and do not require individual laboratory action.

- Exceed EWMA industry chart action limit

  - TMC to notify test developer, surveillance panel chairman, and ACC Monitoring Agency. Meeting of the TMC, test developer, and surveillance panel required to determine course of action.

- Exceed EWMA industry chart warning limit

  - TMC to notify test developer, surveillance panel chairman, and ACC Monitoring Agency. Coordination of TMC, test developer, and surveillance panel chairman required to discuss potential problem.

12. 1K LTMS Requirements

The following are the specific 1K calibration test requirements.

A. Reference Oils and Parameters

The critical parameters are Weighted Demerits and Top Groove Fill. The reference oils required for test stand and test laboratory calibration are reference oils accepted by the ASTM Single Cylinder Diesel Surveillance Panel. The means and standard deviations for the current reference oils for each critical and noncritical parameter are presented below.

WEIGHTED DEMERITS
Unit of Measure: Demerits
CRITICAL PARAMETER

Reference Oil	Mean	Standard Deviation
809	219.2	41.9
809-1	216.4	35.6
811-1	327.7	55.9

TOP GROOVE FILL
Unit of Measure: Percent
CRITICAL PARAMETER

Reference Oil	Mean	Standard Deviation
809	12.3	6.3
809-1	17.5	15.7
811-1	27.3	16.6

TOP LAND HEAVY CARBON
Unit of Measure: LN(TLHC+1)
NONCRITICAL PARAMETER

Reference Oil	Mean	Standard Deviation
809	0.398	0.9
809-1	0.605	1.1
811-1	0.868	1.0

AVERAGE OIL CONSUMPTION
Unit of Measure: g/kW-h
NONCRITICAL PARAMETER

Reference Oil	Mean	Standard Deviation
809	0.272	0.117
809-1	0.268	0.145
811-1	0.267	0.097

B. Acceptance Criteria

1. New Test Stand

a. Less than six (6)* Operationally Valid Calibration Results in Laboratory

- Two (2) operationally valid calibration tests, with no stand Shewhart severity alarms and no stand Shewhart precision alarms for critical parameters, must be conducted on any approved reference oils. The second run must be started not more than 14 days after the completion of the first.

- All critical parameters for 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.

b. Six (6)* or more Operationally Valid Calibration Results in Laboratory and no current laboratory level EWMA or Shewhart precision alarms

- The first operationally valid calibration test run on any approved reference oil must have no stand Shewhart severity alarms and no stand Shewhart precision alarms for critical parameters using the "Reduced K" values. If the first operationally valid calibration test does not meet this acceptance criteria, then the New Test Stand criteria listed above in 1.a must be followed.

* Only test results from calibrated stands in the laboratory count towards the tally. The most recent of those tests must have completed not more than twelve (12) months before the end of the test being considered for "Reduced K".

Examples of stands required to meet New Test Stand acceptance criteria include:

a. an entirely new stand installation that has never before been calibrated.
b. a previously calibrated stand that has undergone significant hardware, software, or control system changes.
c. a previously calibrated stand whose last calibration expired more than one calibration period ago.

2. Existing Test Stand

   - One (1) operationally valid calibration test, with no stand Shewhart severity alarms and no stand Shewhart precision alarms for critical parameters, must be conducted on any approved reference oil.

   - All critical parameters for 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.

   Examples of stands required to meet Existing Test Stand acceptance criteria include:

   a. a previously calibrated stand whose last calibration expired not more than one calibration period ago.
   b. a stand currently calibrated as a 1N stand in a lab with at least one other currently calibrated 1K stand.

3. Reference Oil Assignment

   Once test stands have been accepted into the system, the TMC will assign reference oils for continuing calibration according to the following reference oil mix:

   - 100% of the scheduled calibration tests should be conducted on reference oils 809 and 811, or subsequent approved reblends.

4. Control Charts

   In Section 1, the construction of the control charts that constitute the Lubricant Test Monitoring System is outlined. The constants used for the construction of the control charts for the 1K, and the response necessary in the case of control chart limit alarms, are depicted below. Note that control charting all parameters is required.

LUBRICANT TEST MONITORING SYSTEM CONSTANTS

		EWMA Chart				Shewhart	
		LAMBDA		K		K	
Chart Level	Limit Type	Precision	Severity	Precision	Severity	Precision	Severity
Stand	Reduced K	--	--	--	--	1.48	1.43
	Action	0.3	0.3	1.80	2.10	1.80	1.75
Lab	Warning	0.2	--	1.80	--	--	--
	Action	0.2	0.2	2.58	1.96	1.80	1.75
Industry	Warning	0.15	0.15	1.74	2.05	--	--
	Action	0.15	0.15	2.58	2.81	--	--

The following are the steps that must be taken in the case of exceeding control chart limits. The steps are listed in order of priority, although charts should be studied simultaneously to

determine the cause(s) of a problem. In the case of multiple alarms, contact the TMC for guidance.

- Exceed EWMA laboratory chart action limit for precision (critical parameters only)
  - Immediately provide written notice of the alarm and its meaning to all Test Purchasers and the TMC. This notice shall be appended to all test reports during the alarm period.
- Exceed EWMA laboratory chart warning limit for precision (critical parameters only)
  - Immediately provide written notice of the alarm and its meaning to all Test Purchasers and the TMC. This notice shall be appended to all test reports during the alarm period.
- Exceed EWMA test stand chart limit for precision (critical parameters only)
  - Immediately provide written notice of the alarm and its meaning to all Test Purchasers and the TMC. This notice shall be appended to all test reports for the stand in question during the alarm period.
- Exceed Shewhart test stand chart limit for precision (critical parameters only)
  - Immediately provide written notice of the alarm and its meaning to all Test Purchasers and the TMC. This notice shall be appended to all test reports for the stand in question during the alarm period.
- Exceed Shewhart laboratory chart action limit for precision (critical parameters only)
  - Immediately provide written notice of the alarm and its meaning to all Test Purchasers and the TMC. This notice shall be appended to all test reports during the alarm period.
- Exceed EWMA laboratory chart action limit for severity (all parameters noted below)
  - Calculate laboratory Severity Adjustment (SA) for each parameter that exceeds action limit, using the current laboratory EWMA (Z_i) as follows:

Weighted Demerits:	$SA = (-Z_i) \times (35.6)$*
Top Groove Fill:	$SA = (-Z_i) \times (15.7)$*
Top Land Heavy Carbon:	$SA = (-Z_i) \times (1.1)$*

    * s based on reference oil 809-1

  - Confirm calculations with the TMC.

- Exceed EWMA test stand chart limit for severity (critical parameters only)

  - Notify the TMC. If the direction of the test stand severity is deemed different from that of the test laboratory, conduct an additional calibration test in the identified test stand. If this limit is still exceeded after the additional calibration test, then remove test stand from the system, notify the TMC, correct test stand severity problem, and follow requirements for entry of a new test stand into the system.

- Exceed Shewhart test stand chart limit for severity (all parameters except Average Oil Consumption)

  - Conduct an additional calibration test.

- Exceed 0.5 g/kWh Average Oil Consumption

  - Conduct an additional calibration test.

The following industry issues are handled by the TMC and do not require individual laboratory action.

- Exceed EWMA industry chart action limit (all parameters)

  - TMC to notify test developer, surveillance panel chairman, and ACC Monitoring Agency. Meeting of TMC, test developer, and surveillance panel required to determine course of action.

- Exceed EWMA industry chart warning limit (all parameters)

  - TMC to notify test developer, surveillance panel chairman, and ACC Monitoring Agency. Coordination of TMC, test developer, and surveillance panel chairman required to discuss potential problem.

13. 1N LTMS Requirements

The following are the specific 1N calibration test requirements.

A. Reference Oils and Parameters

The critical parameters are Weighted Demerits and Top Groove Fill. The reference oils required for test stand and test laboratory calibration are reference oils accepted by the ASTM Single Cylinder Diesel Surveillance Panel. The means and standard deviations for the current reference oils for each critical and noncritical parameter are presented below.

WEIGHTED DEMERITS
Unit of Measure: Demerits
CRITICAL PARAMETER

Reference Oil	Mean	Standard Deviation
809-1	205.0	34.6
811-1	273.2	35.5
811-2	281.5	37.4
1004-2	204.0	25.7
1004-3	190.7	24.7

TOP GROOVE FILL
Unit of Measure: Percent
CRITICAL PARAMETER

Reference Oil	Mean	Standard Deviation
809-1	35.3	20.5
811-1	26.2	19.8
811-2	24.7	21.6
1004-2	30.4	16.8
1004-3	23.9	14.6

TOP LAND HEAVY CARBON
Unit of Measure: LN(TLHC+1)
NONCRITICAL PARAMETER

Reference Oil	Mean	Standard Deviation
809-1	1.1970	1.2130
811-1	0.454	0.6590
811-2	0.366	0.6000
1004-2	0.4900	0.8040
1004-3	0.1806	0.3977

AVERAGE OIL CONSUMPTION

Unit of Measure: g/kW-h
NONCRITICAL PARAMETER

Reference Oil	Mean	Standard Deviation
809-1	0.308	0.175
811-1	0.218	0.053
811-2	0.223	0.052
1004-2	0.206	0.075
1004-3	0.148	0.038

B. Acceptance Criteria

1. New Test Stand

a. Less than six (6)* Operationally Valid Calibration Results in Laboratory

- Two (2) operationally valid calibration tests, with no stand Shewhart severity alarms and no stand Shewhart precision alarms for critical parameters, must be conducted on any approved reference oils. The second run must be started not more than 14 days after the completion of the first.

- All critical parameters for 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.

b. Six (6)* or more Operationally Valid Calibration Results in Laboratory and no current laboratory level EWMA or Shewhart precision alarms

- The first operationally valid calibration test run on any approved reference oil must have no stand Shewhart severity alarm and no stand Shewhart precision alarms for critical parameters using the "Reduced K" values. If the first operationally valid calibration test does not meet this acceptance criteria, then the New Test Stand criteria listed above in 1.a must be followed.

* Only test results from calibrated stands in the laboratory count towards the tally. The most recent of those tests must have completed not more than twelve (12) months before the end of the test being considered for "Reduced K".

Examples of stands required to meet New Test Stand acceptance criteria include:

a. an entirely new stand installation that has never before been calibrated.
d. a previously calibrated stand that has undergone significant hardware, software, or control system changes.
e. a previously calibrated stand whose last calibration expired more than one calibration period ago.

2. Existing Test Stand

   - One (1) operationally valid calibration test, with no stand Shewhart severity alarms and no stand Shewhart precision alarms for critical parameters, must be conducted on any approved reference oil.

   - All critical parameters for 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.

   Examples of stands required to meet Existing Test Stand acceptance criteria include:

   a. a previously calibrated stand whose last calibration expired not more than one calibration period ago.
   b. a stand currently calibrated as a 1K stand in a lab with at least one other currently calibrated 1N stand

3. Reference Oil Assignment

   Once test stands have been accepted into the system, the TMC will assign reference oils for continuing calibration according to the following reference oil mix:

   - Calibration tests should be conducted on reference oils 809-1, and 811-1, or subsequent approved reblends.

4. Control Charts

   In Section 1, the construction of the control charts that constitute the Lubricant Test Monitoring System is outlined. The constants used for the construction of the control charts for the 1N, and the response necessary in the case of control chart limit alarms, are depicted below. Note that control charting all parameters is required.

LUBRICANT TEST MONITORING SYSTEM CONSTANTS

		EWMA Chart				Shewhart Chart	
		LAMBDA		K		K	
Chart Level	Limit Type	Precision	Severity	Precision	Severity	Precision	Severity
Stand	Reduced K	--	--	--	--	1.48	1.43
	Action	0.3	0.3	1.80	2.10	1.80	1.75
Lab	Warning	0.2	--	1.80	--	--	--
	Action	0.2	0.2	2.58	1.96	1.80	1.75
Industry	Warning	0.15	0.15	1.74	2.05	--	--
	Action	0.15	0.15	2.58	2.81	--	--

The following are the steps that must be taken in the case of exceeding control chart limits. The steps are listed in order of priority, although charts should be studied simultaneously to determine the cause(s) of a problem. In the case of multiple alarms, contact the TMC for guidance.

- Exceed EWMA laboratory chart action limit for precision (critical parameters only)

  – Immediately provide written notice of the alarm and its meaning to all Test Purchasers and the TMC. This notice shall be appended to all test reports during the alarm period.

- Exceed EWMA laboratory chart warning limit for precision (critical parameters only)

  – Immediately provide written notice of the alarm and its meaning to all Test Purchasers and the TMC. This notice shall be appended to all test reports during the alarm period.

- Exceed EWMA test stand chart limit for precision (critical parameters only)

  – Immediately provide written notice of the alarm and its meaning to all Test Purchasers and the TMC. This notice shall be appended to all test reports for the stand in question during the alarm period.

- Exceed Shewhart test stand chart limit for precision (critical parameters only)

  – Immediately provide written notice of the alarm and its meaning to all Test Purchasers and the TMC. This notice shall be appended to all test reports for the stand in question during the alarm period.

- Exceed Shewhart laboratory chart action limit for precision (critical parameters only)

  – Immediately provide written notice of the alarm and its meaning to all Test Purchasers and the TMC. This notice shall be appended to all test reports during the alarm period.

- Exceed EWMA laboratory chart action limit for severity (all parameters noted below)

  – Calculate laboratory Severity Adjustment (SA) for each parameter that exceeds action limit, using the current laboratory EWMA (Z_i) as follows:

Weighted Demerits:	$SA = (-Z_i) \times (27.1)$*
Top Groove Fill:	$SA = (-Z_i) \times (14.6)$*
Top Land Heavy Carbon:	$SA = (-Z_i) \times (0.9)$*

    * s based on reference oil 1004-1

  – Confirm calculations with the TMC.

- Exceed EWMA test stand chart limit for severity (critical parameters only)

  - Notify the TMC. If the direction of the test stand severity is deemed different from that of the test laboratory, conduct an additional calibration test in the identified test stand. If this limit is still exceeded after the additional calibration test, then remove test stand from the system, notify the TMC, correct test stand severity problem, and follow requirements for entry of a new test stand into the system.

- Exceed Shewhart test stand chart limit for severity (all parameters except Average Oil Consumption)

  - Conduct an additional calibration test.

- Exceed 0.5 g/kWh Average Oil Consumption

  - Conduct an additional calibration test.

The following industry issues are handled by the TMC and do not require individual laboratory action.

- Exceed EWMA industry chart action limit (all parameters)

  - TMC to notify test developer, surveillance panel chairman, and ACC Monitoring Agency. Meeting of TMC, test developer, and surveillance panel required to determine course of action.

- Exceed EWMA industry chart warning limit (all parameters)

  - TMC to notify test developer, surveillance panel chairman, and ACC Monitoring Agency. Coordination of TMC, test developer, and surveillance panel chairman required to discuss potential problem.

14. 1P LTMS Requirements

The following are the specific 1P calibration test requirements.

A. Reference Oils and Parameters

The critical parameters are Top Groove Carbon, Top Land Carbon and Average Oil Consumption. The reference oils required for test stand and test laboratory calibration are reference oils accepted by the ASTM Single Cylinder Diesel Surveillance Panel. The means and standard deviations for the current reference oils for each critical and noncritical parameter are presented below.

TOP GROOVE CARBON
Unit of Measure: Demerits
CRITICAL PARAMETER

Reference Oil	Mean	Standard Deviation
1004-3	29.48	7.74
1005-3	28.65	7.74
1005-4	28.65	7.74

TOP LAND CARBON
Unit of Measure: Demerits
CRITICAL PARAMETER

Reference Oil	Mean	Standard Deviation
1004-3	28.12	13.15
1005-3	30.88	13.15
1005-4	30.88	13.15

AVERAGE OIL CONSUMPTION
Unit of Measure: LN(g/h)
CRITICAL PARAMETER

Reference Oil	Mean	Standard Deviation
1004-3	1.8321	0.3238
1005-3	1.8641	0.3238
1005-4	1.8641	0.3238

WEIGHTED DEMERITS
Unit of Measure: Demerits
NONCRITICAL PARAMETER

Reference Oil	Mean	Standard Deviation
1004-3	319.6	57.6
1005-3	285.3	57.6
1005-4	285.3	57.6

END OF TEST OIL CONSUMPTION
Unit of Measure: LN(g/h)
NONCRITICAL PARAMETER

Reference Oil	Mean	Standard Deviation
1004-3	2.0492	0.5177
1005-3	1.6016	0.5177
1005-4	1.6016	0.5177

B. Acceptance Criteria

1. New Test Stand

a. Less than six (6) Operationally Valid Calibration Results in Laboratory

- A minimum of two (2) operationally valid calibration tests, with no stand Shewhart severity alarms and no stand Shewhart precision alarms, must be conducted on any approved reference oils.

- 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.

b. Six (6) or more Operationally Valid Calibration Results in Laboratory *

- The first operationally valid calibration test run on any approved reference oil must have no stand Shewhart severity alarm and no stand Shewhart precision alarm using the "Reduced K" values. If the first operationally valid calibration test does not meet this acceptance criteria, then the New Test Stand criteria listed above in 1.a must be followed.

* Only test results from calibrated stands in the laboratory count towards the tally of six (6) required operationally valid calibration tests. The sixth test must complete (date and time) before the first test completes (date and time) on a New Test Stand that is seeking calibration with a single test result. In addition, the first test for the stand is to begin within nine (9) months of the completion of the last acceptable calibration test. Also, there must not be any outstanding precision alarms for the laboratory.

2. Existing Test Stand

   - The test stand must have been TMC calibrated prior to LTMS introduction or previously accepted into the system by meeting LTMS calibration requirements.

   - 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.

3. Reference Oil Assignment

   Once test stands have been accepted into the system, the TMC will assign reference oils for continuing calibration according to the following reference oil mix:

   - 80% of the scheduled calibration tests should be conducted on reference oil 1005 or subsequent approved reblend.

   - 20% of the scheduled calibration tests should be conducted on reference oils 1004-3 or subsequent approved reblends.

4. Control Charts

   In Section 1, the construction of the control charts that constitute the Lubricant Test Monitoring System is outlined. The constants used for the construction for the control charts for the 1P, and the response necessary in the case of control chart limit alarms, are depicted below. Note that control charting all parameters is required.

LUBRICANT TEST MONITORING SYSTEM CONSTANTS

		EWMA Chart				Shewhart Chart	
		LAMBDA		K		K	
Chart Level	Limit Type	Precision	Severity	Precision	Severity	Precision	Severity
Stand	Reduced K	--	--	--	--	1.66	1.48
	Action	0.3	0.3	1.96	2.24	1.96	1.80
Lab	Warning	0.2	--	1.96	--	--	--
	Action	0.2	0.2	2.72	1.96	1.96	1.80
Industry	Warning	0.2	0.2	2.00	2.24	--	--
	Action	0.2	0.2	2.65	2.88	--	--

The following are the steps that must be taken in the case of exceeding control chart limits. The steps are listed in order of priority, although charts should be studied simultaneously to determine the cause(s) of a problem. In the case of multiple alarms, contact the TMC for guidance.

- Exceed EWMA laboratory chart action limit for precision (critical parameters only).
  - Immediately provide written notice of the alarm and its meaning to all Test Purchasers and the TMC. This notice shall be appended to all test reports during the alarm period.
- Exceed EWMA laboratory chart warning limit for precision (critical parameters only)
  - Immediately provide written notice of the alarm and its meaning to all Test Purchasers and the TMC. This notice shall be appended to all test reports during the alarm period.
- Exceed EWMA test stand chart limit for precision (critical parameters only)
  - Immediately provide written notice of the alarm and its meaning to all Test Purchasers and the TMC. This notice shall be appended to all test reports for the stand in question during the alarm period.
- Exceed Shewhart test stand chart limit for precision (critical parameters only)
  - Immediately provide written notice of the alarm and its meaning to all Test Purchasers and the TMC. This notice shall be appended to all test reports for the stand in question during the alarm period.
- Exceed Shewhart laboratory chart action limit for precision (critical parameters only)
  - Immediately provide written notice of the alarm and its meaning to all Test Purchasers and the TMC. This notice shall be appended to all test reports during the alarm period.
- Exceed EWMA laboratory chart action limit for severity (all parameters)
  - Calculate laboratory Severity Adjustment (SA) for each parameter that exceeds action limit, using the current laboratory EWMA (Z_i) as follows:

Top Groove Carbon:	$SA = (-Z_i) \times (7.74)$
Top Land Heavy Carbon:	$SA = (-Z_i) \times (13.15)$
Average Oil Consumption:	$SA = (-Z_i) \times (0.3238)$
Weighted Demerits:	$SA = (-Z_i) \times (57.6)$
End of Test Oil Consumption:	$SA = (-Z_i) \times (0.5177)$

  - Confirm calculations with the TMC.
- Exceed EWMA test stand chart limit for severity (critical parameters only)
  - Notify the TMC. If the direction of the test stand severity is deemed different from that of the test laboratory, conduct an additional calibration test in the identified test stand. If this limit is still exceeded after the additional calibration test, then remove

est stand from the system, notify the TMC, correct test stand severity problem, and follow requirements for entry of a new test stand into the system.

- Exceed Shewhart test stand chart limit for severity (all parameters)
  - Conduct an additional calibration test.

The following industry issues are handled by the TMC and do not require individual laboratory action.

- Exceed EWMA industry chart action limit (all parameters)
  - TMC to notify test developer, surveillance panel chairman, and ACC Monitoring Agency. Meeting of TMC, test developer, and surveillance panel required to determine course of action.
- Exceed EWMA industry chart warning limit (all parameters)
  - TMC to notify test developer, surveillance panel chairman, and ACC Monitoring Agency. Coordination of TMC, test developer and surveillance panel chairman required to discuss potential problem.

15. 1R LTMS Requirements

The following are the specific 1R calibration test requirements.

A. Reference Oils and Parameters

The critical parameters are Weighted Demerits, Top Groove Carbon, and Top Land Carbon. The reference oils required for test stand and test laboratory calibration are reference oils accepted by the ASTM Single Cylinder Diesel Surveillance Panel. The means and standard deviations for the current reference oils for each critical and noncritical parameter are presented below.

WEIGHTED DEMERITS
Unit of Measure: Demerits
CRITICAL PARAMETER

Reference Oil	Mean	Standard Deviation
820-2	341.2	36.2
1005-3	327.9	23.1
1005-4	327.9	23.1

TOP GROOVE CARBON
Unit of Measure: Demerits
CRITICAL PARAMETER

Reference Oil	Mean	Standard Deviation
820-2	34.11	10.28
1005-3	34.51	8.70
1005-4	34.51	8.70

TOP LAND CARBON
Unit of Measure: Demerits
CRITICAL PARAMETER

Reference Oil	Mean	Standard Deviation
820-2	22.82	10.50
1005-3	18.61	6.00
1005-4	18.61	6.00

INITIAL OIL CONSUMPTION
Unit of Measure: g/h
NONCRITICAL PARAMETER

Reference Oil	Mean	Standard Deviation
820-2	8.3	1.7
1005-3	10.0	1.1
1005-4	10.0	1.1

END OF TEST OIL CONSUMPTION
Unit of Measure: g/h
NONCRITICAL PARAMETER

Reference Oil	Mean	Standard Deviation
820-2	7.9	2.6
1005-3	8.3	1.0
1005-4	8.3	1.0

B. Acceptance Criteria

1. New Test Stand

a. Less than three (3) Operationally Valid Calibration Results in Laboratory

- A minimum of two (2) operationally valid calibration tests, with no stand Shewhart severity alarms and no stand Shewhart precision alarms, must be conducted on any approved reference oils.

- 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.

b. Three (3) or more Operationally Valid Calibration Results in Laboratory *

- The first operationally valid calibration test run on any approved reference oil must have no stand Shewhart severity alarm and no stand Shewhart precision alarm using the "Reduced K" values. If the first operationally valid calibration test does not meet this acceptance criteria, then the New Test Stand criteria listed above in 1.a must be followed.

* Only test results from calibrated stands in the laboratory count towards the tally of three (3) required operationally valid calibration tests. The third test must complete (date and time) before the first test completes (date and time) on a New Test Stand that is seeking calibration with a single test result. In addition, the first test for the stand is to begin within twelve (12) months of the completion of the last acceptable calibration test. Also, there must not be any outstanding precision alarms for the laboratory.

2. Existing Test Stand

   - The test stand must have been TMC calibrated prior to LTMS introduction or previously accepted into the system by meeting LTMS calibration requirements. Any stand that has not completed a calibration test for two or more years is required to meet the New Test Stand criteria listed above in 1.a.

   - 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.

3. Reference Oil Assignment

   Once test stands have been accepted into the system, the TMC will assign reference oils for continuing calibration according to the following reference oil mix:

   - 75% of the scheduled calibration tests should be conducted on reference oil 820 or subsequent approved reblends.

   - 25% of the scheduled calibration tests should be conducted on reference oils 1005-1 or subsequent approved reblends.

4. Control Charts

   In Section 1, the construction of the control charts that constitute the Lubricant Test Monitoring System is outlined. The constants used for the construction for the control charts for the 1R, and the response necessary in the case of control chart limit alarms, are depicted below. Note that control charting all parameters is required.

LUBRICANT TEST MONITORING SYSTEM CONSTANTS

		EWMA Chart				Shewhart Chart	
		LAMBDA		K		K	
Chart Level	Limit Type	Precision	Severity	Precision	Severity	Precision	Severity
Stand	Reduced K	--	--	--	--	1.48	1.48
	Action	0.3	0.3	1.48	2.45	1.48	1.80
Lab	Warning	0.3	--	1.48	--	--	--
	Action	0.3	0.2	2.33	1.96	1.48	1.80
Industry	Warning	0.2	0.2	1.48	1.80	--	--
	Action	0.2	0.2	2.33	2.58	--	--

The following are the steps that must be taken in the case of exceeding control chart limits. The steps are listed in order of priority, although charts should be studied simultaneously to determine the cause(s) of a problem. In the case of multiple alarms, contact the TMC for guidance.

- Exceed EWMA laboratory chart action limit for precision (critical parameters only).

  - Immediately provide written notice of the alarm and its meaning to all Test Purchasers and the TMC. This notice shall be appended to all test reports during the alarm period.

- Exceed EWMA laboratory chart warning limit for precision (critical parameters only)

  - Immediately provide written notice of the alarm and its meaning to all Test Purchasers and the TMC. This notice shall be appended to all test reports during the alarm period.

- Exceed EWMA test stand chart limit for precision (critical parameters only)

  - Immediately provide written notice of the alarm and its meaning to all Test Purchasers and the TMC. This notice shall be appended to all test reports for the stand in question during the alarm period.

- Exceed Shewhart test stand chart limit for precision (critical parameters only)

  - Immediately provide written notice of the alarm and its meaning to all Test Purchasers and the TMC. This notice shall be appended to all test reports for the stand in question during the alarm period.

- Exceed Shewhart laboratory chart action limit for precision (critical parameters only)

  - Immediately provide written notice of the alarm and its meaning to all Test Purchasers and the TMC. This notice shall be appended to all test reports during the alarm period.

- Exceed EWMA laboratory chart action limit for severity (all parameters)

  - Calculate laboratory Severity Adjustment (SA) for each parameter that exceeds action limit, using the current laboratory EWMA (Z_i) as follows:

Weighted Demerits:	$SA = (-Z_i) \times (29.0)$
Top Groove Carbon:	$SA = (-Z_i) \times (9.70)$
Top Land Heavy Carbon:	$SA = (-Z_i) \times (7.84)$
Initial Oil Consumption:	$SA = (-Z_i) \times (1.32)$
End of Test Oil Consumption:	$SA = (-Z_i) \times (1.35)$

  - Confirm calculations with the TMC.

- Exceed EWMA test stand chart limit for severity (critical parameters only)

  - Notify the TMC. If the direction of the test stand severity is deemed different from that of the test laboratory, conduct an additional calibration test in the identified test stand. If this limit is still exceeded after the additional calibration test, then remove test stand from the system, notify the TMC, correct test stand severity problem, and follow requirements for entry of a new test stand into the system.

- Exceed Shewhart test stand chart limit for severity (all parameters)
  - Conduct an additional calibration test.

The following industry issues are handled by the TMC and do not require individual laboratory action.

- Exceed EWMA industry chart action limit (all parameters)
  - TMC to notify test developer, surveillance panel chairman, and ACC Monitoring Agency. Meeting of TMC, test developer, and surveillance panel required to determine course of action.
- Exceed EWMA industry chart warning limit (all parameters)
  - TMC to notify test developer, surveillance panel chairman, and ACC Monitoring Agency. Coordination of TMC, test developer and surveillance panel chairman required to discuss potential problem.

16. C13 LTMS Requirements

The following are the specific C13 calibration test requirements.

A. Reference Oils and Parameters

The critical parameters are Top Groove Carbon, Top Land Carbon, Oil Consumption Delta, and Second Ring Top Carbon. The reference oils required for test stand and test laboratory calibration are reference oils accepted by the ASTM C13 Surveillance Panel. The mean and standard deviation for the current reference oils for test parameters are presented below.

TOP GROOVE CARBON
Unit of Measure: Demerits

Reference Oil	Mean	Standard Deviation
831	46.02	5.90
831-1	46.02	5.90
831-2	46.02	5.90

TOP LAND CARBON
Unit of Measure: Demerits

Reference Oil	Mean	Standard Deviation
831	21.87	7.89
831-1	21.87	7.89
831-2	21.87	7.89

OIL CONSUMPTION DELTA
Unit of Measure: SQRT (g/h)

Reference Oil	Mean	Standard Deviation
831	5.5089	0.7141
831-1	5.5089	0.7141
831-2	5.5089	0.7141

SECOND RING TOP CARBON
Unit of Measure: LN (Demerits)

Reference Oil	Mean	Standard Deviation
831	2.8828	0.2900
831-1	2.8828	0.2900
831-2	2.8828	0.2900

B. Acceptance Criteria

1. New Test Stand

   a. First Test Stand in a Laboratory

      - A minimum of two (2) operationally valid calibration tests with no stand Shewhart severity alarms, must be conducted on any approved reference oil.

   b. All Subsequent New Test Stands in a Laboratory

      - One operationally valid test with no stand Shewhart severity alarms must be conducted on any approved reference oil.

2. Existing Test Stand

   - The test stand must have been previously accepted into the system by meeting LTMS calibration requirements.

   - One operationally valid test with no stand Shewhart severity alarms must be conducted on any approved reference oil.

3. Reference Oil Assignment

   Once test stands have been accepted into the system, the TMC will assign reference oils for continuing calibration according to the following reference oil mix:

   - 100% of the scheduled calibration tests should be conducted on reference oil 831 (or subsequent approved reblends).

4. Control Charts

   In Section 1, the construction of the four control charts that constitute the Lubricant Test Monitoring System is outlined. The constants used for the construction of the control charts for the C13, and the response necessary in the case of control chart limit alarms, are depicted below.

LUBRICANT TEST MONITORING SYSTEM CONSTANTS

		EWMA Chart				Shewhart Chart	
		LAMBDA		K		K	
Chart Level	Limit Type	Precision	Severity	Precision	Severity	Precision	Severity
Stand	Action	0.3	0.3	1.80	2.10	1.80	2.00
Industry	Warning	0.2	0.2	1.74	2.05	--	--
	Action	0.2	0.2	2.58	2.81	--	--

The following are the steps that must be taken in the case of exceeding control chart limits.

- Exceed Shewhart test stand chart limit for severity
  - Conduct an additional calibration test.

The following industry issues are handled by the TMC and do not require individual laboratory action.

- Exceed EWMA industry chart action limit
  - TMC to notify test developer, surveillance panel chairman, and ACC Monitoring Agency. Meeting of TMC, test developer, and surveillance panel required to determine course of action.
- Exceed EWMA industry chart warning limit
  - TMC to notify test developer, surveillance panel chairman, and ACC Monitoring Agency. Coordination of TMC, test developer, and surveillance panel chairman required to discuss potential problem.

17. ISB LTMS Requirements

The following are the specific ISB calibration test requirements.

A. Reference Oils and Parameters

The critical parameters are Average Cam Shaft Wear and Average Tappet Weight Loss. The reference oils required for test stand and test laboratory calibration are reference oils accepted by the ASTM Cummins Test Surveillance Panel. The mean and standard deviation for the current reference oils for each critical parameter are presented below.

AVERAGE CAM SHAFT WEAR
Unit of Measure: Micrometers

Reference Oil	Mean	Standard Deviation
831	42.5	5.0
831-1	42.5	5.0
831-2	42.5	5.0

AVERAGE TAPPET WEIGHT LOSS
Unit of Measure: Milligrams

Reference Oil	Mean	Standard Deviation
831	97.2	14.8
831-1	97.2	14.8
831-2	97.2	14.8

B. Acceptance Criteria

1. New Test Stand

   a. First Test Stand in a Laboratory

   - A minimum of two (2) operationally valid calibration tests with no stand Shewhart severity alarms must be conducted on any approved reference oil.

   b. All Subsequent New Test Stands in a Laboratory

   - One operationally valid test with no stand Shewhart severity alarms must be conducted on any approved reference oil.

2. Existing Test Stand

   - The test stand must have been previously accepted into the system by meeting LTMS calibration requirements.

- One operationally valid test test with no stand Shewhart severity alarms must be conducted on any approved reference oil.

3. Reference Oil Assignment

Once test stands have been accepted into the system, the TMC will assign reference oils for continuing calibration according to the following reference oil mix:

- 100% of the scheduled calibration tests should be conducted on reference oil 831 (or subsequent approved reblends).

4. Control Charts

In Section 1, the construction of the four control charts that constitute the Lubricant Test Monitoring System is outlined. The constants used for the construction of the control charts for the ISB, and the response necessary in the case of control chart limit alarms, are depicted below.

LUBRICANT TEST MONITORING SYSTEM CONSTANTS

		EWMA Chart				Shewhart Chart	
		LAMBDA		K		K	
Chart Level	Limit Type	Precision	Severity	Precision	Severity	Precision	Severity
Stand	Action	0.3	0.3	2.10	2.36	2.10	1.96
Industry	Warning	0.2	0.2	2.10	2.36	--	--
	Action	0.2	0.2	2.80	3.00	--	--

The following are the steps that must be taken in the case of exceeding control chart limits.

- Exceed Shewhart test stand chart limit for severity
  - Conduct an additional calibration test.

The following industry issues are handled by the TMC and do not require individual laboratory action.

- Exceed EWMA industry chart action limit
  - TMC to notify test developer, surveillance panel chairman, and ACC Monitoring Agency. Meeting of TMC, test developer, and surveillance panel required to determine course of action.

- Exceed EWMA industry chart warning limit
  - TMC to notify test developer, surveillance panel chairman, and ACC Monitoring Agency. Coordination of TMC, test developer, and surveillance panel chairman required to discuss potential problem.

18. ISM LTMS Requirements

The following are the specific ISM calibration test requirements.

A. Reference Oils and Parameters

The critical parameters are Crosshead Wear at 3.9 % Soot, Oil Filter ΔP, and Average Sludge Rating. Injector Adjusting Screw Wear at 3.9% Soot is a non-critical parameter. The reference oils required for test stand and test laboratory calibration are reference oils accepted by the ASTM Cummins Surveillance Panel. The mean and standard deviation for the current reference oils for critical and non-critical parameters are presented below.

CROSSHEAD WEAR AT 3.9% SOOT
Unit of Measure: Milligrams
CRITICAL PARAMETER

Reference Oil	Mean	Standard Deviation
830-2	5.1	1.5

OIL FILTER ΔP
Unit of Measure: LN(OFDP+1)
CRITICAL PARAMETER

Reference Oil	Mean	Standard Deviation
830-2	2.5209	0.3274

AVERAGE SLUDGE RATING
Unit of Measure: Merit Rating
CRITICAL PARAMETER

Reference Oil	Mean	Standard Deviation
830-2	9.00	0.15

INJECTOR ADJUSTING SCREW WEAR AT 3.9% SOOT
Unit of Measure: Milligrams
NON-CRITICAL PARAMETER

Reference Oil	Mean	Standard Deviation
830-2	29.5	5.7

B. Acceptance Criteria

1. New Test Stand

a. First Test Stand in a Laboratory

- A minimum of two (2) operationally valid calibration tests with no stand Shewhart severity alarms (critical parameters only), must be conducted on any approved reference oil.

b. All Subsequent New Test Stands in a Laboratory

- One operationally valid test with no stand Shewhart severity alarms (critical parameters only) must be conducted on any approved reference oil.

2. Existing Test Stand

- The test stand must have been previously accepted into the system by meeting LTMS calibration requirements.

3. Reference Oil Assignment

Once test stands have been accepted into the system, the TMC will assign reference oils for continuing calibration according to the following reference oil mix:

- 100% of the scheduled calibration tests should be conducted on reference oil 830-2 or subsequent approved reblends.

4. Control Charts

In Section 1, the construction of the four control charts that constitute the Lubricant Test Monitoring System is outlined. The constants used for the construction of the control charts for the ISM, and the response necessary in the case of control chart limit alarms, are depicted below.

LUBRICANT TEST MONITORING SYSTEM CONSTANTS

		EWMA Chart				Shewhart Chart	
		LAMBDA		K		K	
Chart Level	Limit Type	Precision	Severity	Precision	Severity	Precision	Severity
Stand	Action	0.3	0.3	2.10	2.36	2.10	1.80
Industry	Warning	0.2	0.2	2.10	2.36	--	--
	Action	0.2	0.2	2.80	3.00	--	--

The following are the steps that must be taken in the case of exceeding control chart limits.

- Exceed Shewhart test stand chart limit for severity (critical parameters only)
  - Conduct an additional calibration test.

The following industry issues are handled by the TMC and do not require individual laboratory action.

- Exceed EWMA industry chart action limit
  - TMC to notify test developer, surveillance panel chairman, and ACC Monitoring Agency. Meeting of TMC, test developer, and surveillance panel required to determine course of action.
  -
- Exceed EWMA industry chart warning limit
  - TMC to notify test developer, surveillance panel chairman, and ACC Monitoring Agency. Coordination of TMC, test developer, and surveillance panel chairman required to discuss potential problem.

19. T-8 / T-8E LTMS Requirements

The following are the specific T-8 and T-8E calibration test requirements.

A. Reference Oils and Parameters

The critical parameters are Viscosity Increase at 3.8% Soot (T-8 and T-8E) and Relative Viscosity at 4.8% Soot, 50% DIN Shear Loss (T-8E only). Relative Viscosity at 4.8% Soot, 100% DIN Shear Loss is a non-critical parameter (T-8E only). The reference oils required for test stand and test laboratory calibration are reference oils accepted by the ASTM Mack Test Surveillance Panel. The mean and standard deviation for the current reference oils for each critical and non-critical parameter are presented below.

VISCOSITY INCREASE @ 3.8% SOOT
Unit of Measure: cSt
CRITICAL PARAMETER

Reference Oil	Mean	Standard Deviation
1005-3	5.01	0.56
1005-4	5.01	0.56

RELATIVE VISCOSITY @ 4.8% SOOT
50% DIN Shear Loss
Unit of Measure: unitless
CRITICAL PARAMETER

Reference Oil	Mean	Standard Deviation
1005-3	1.76	0.08
1005-4	1.76	0.08

RELATIVE VISCOSITY @ 4.8% SOOT
100% DIN Shear Loss
Unit of Measure: unitless
NON-CRITICAL PARAMETER

Reference Oil	Mean	Standard Deviation
1005-3	2.00	0.09
1005-4	2.00	0.09

B. Acceptance Criteria

1. New Test Stand

a. Less than four (4) Operationally Valid Calibration Results in Laboratory

- A minimum of two (2) operationally valid calibration tests with no stand Shewhart severity alarms, must be conducted on any approved reference oil.

- 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.

b. Four (4) or more Operationally Valid Calibration Results in Laboratory*

- The first operationally valid calibration test run on any approved reference oil must have no stand Shewhart severity alarms using the "Reduced K" values. If the first operationally valid calibration test does not meet this acceptance criteria, then the New Test Stand criteria listed above in 1.a must be followed.

* Only test results from calibrated stands in the laboratory count toward the tally of four (4) required operationally valid calibration tests. The fourth test must complete (date and time) before the first test completes (date and time) on a New Test Stand that is seeking calibration with a single test result. In addition, the first test for the stand is to begin within eighteen (18) months of the completion of the last acceptable calibration test.

c. Stand for which a lapse in calibration is not greater than two years.

- The first operationally valid calibration test run on any approved reference oil must have no stand Shewhart severity alarm using the "Reduced K" values. If the first operationally valid calibration test does not meet this acceptance criteria, then the New Test Stand criteria listed above in 1.a must be followed.

2. Existing Test Stand

- The test stand must have been an ASTM TMC calibrated test stand prior to LTMS introduction or have previously been accepted into the system by meeting LTMS calibration requirements.

- For Viscosity Increase @ 3.8% Soot, results of all operationally valid calibration tests starting on or after April 1, 1994 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.

- For Relative Viscosity @ 4.8% Soot, 50% DIN Shear Loss, results of all operationally valid 300 hour calibration tests starting on or after January 14, 1997 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.

- For Relative Viscosity @ 4.8% Soot, 100% DIN Shear Loss, results of all operationally valid 300 hour calibration tests 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.

3. Reference Oil Assignment

   Once test stands have been accepted into the system, the TMC will assign reference oils for continuing calibration according to the following reference oil mix:

   - 100% of the scheduled calibration tests should be conducted on reference oil 1005-2 or subsequent approved reblends.

4. Control Charts

   In Section 1, the construction of the control charts that constitute the Lubricant Test Monitoring System is outlined. The constants used for the construction of the control charts for the T-8 and T-8E, and the response necessary in the case of control chart limit alarms, are depicted below.

LUBRICANT TEST MONITORING SYSTEM CONSTANTS

		EWMA Chart				Shewhart Chart	
		LAMBDA		K		K	
Chart Level	Limit Type	Precision	Severity	Precision	Severity	Precision	Severity
Stand	Reduced	--	--	--	--	--	1.43
	Action	0.3	0.3	1.74	2.05	1.74	1.75
Lab	Warning	0.2	--	1.74	--	--	--
	Action	0.2	0.2	2.58	1.96	1.74	1.75
Industry	Warning	0.2	0.2	1.74	2.05	--	--
	Action	0.2	0.2	2.58	2.81	--	--

The following are the steps that must be taken in the case of exceeding control chart limits. The steps are listed in order of priority, although charts should be studied simultaneously to determine the cause(s) of a problem. In the case of multiple alarms, contact the TMC for guidance.

- Exceed EWMA laboratory chart action limit for precision (critical parameters only)
  - Immediately provide written notice of the alarm and its meaning to all Test Purchasers and the TMC. This notice shall be appended to all test reports during the alarm period.
- Exceed EWMA laboratory chart warning limit for precision (critical parameters only)
  - Immediately provide written notice of the alarm and its meaning to all Test Purchasers and the TMC. This notice shall be appended to all test reports during the alarm period.

- Exceed EWMA test stand chart limit for precision (critical parameters only)

  – Immediately provide written notice of the alarm and its meaning to all Test Purchasers and the TMC. This notice shall be appended to all test reports for the stand in question during the alarm period.

- Exceed Shewhart test stand chart limit for precision (critical parameters only)

  – Immediately provide written notice of the alarm and its meaning to all Test Purchasers and the TMC. This notice shall be appended to all test reports for the stand in question during the alarm period.

- Exceed Shewhart laboratory chart action limit for precision (critical parameters only)

  – Immediately provide written notice of the alarm and its meaning to all Test Purchasers and the TMC. This notice shall be appended to all test reports during the alarm period.

- Exceed EWMA laboratory chart action limit for severity (all parameters)

  – Calculate laboratory Severity Adjustment (SA) using the current laboratory EWMA (Z_i) as follows:

Viscosity Increase at 3.8% Soot:	$SA = (-Z_i) \times (0.56)$*
Relative Viscosity at 4.8% Soot, 50% DIN Shear Loss:	$SA = (-Z_i) \times (0.08)$*
Relative Viscosity at 4.8% Soot, 100% DIN Shear Loss:	$SA = (-Z_i) \times (0.09)$*

    * s based on reference oil 1005 and reblends

  – Confirm calculations with the TMC.

- Exceed EWMA test stand chart limit for severity (critical parameters only)

  – Notify the TMC. If the direction of the test stand severity is deemed different from that of the test laboratory, conduct an additional calibration test in the identified test stand. If this limit is still exceeded after the additional calibration test, then remove test stand from the system, notify the TMC, correct test stand severity problem, and follow requirements for entry of a new test stand into the system.

- Exceed Shewhart test stand chart limit for severity (critical parameters only)

  – Conduct an additional calibration test.

The following industry issues are handled by the TMC and do not require individual laboratory action.

- Exceed EWMA industry chart action limit
  - TMC to notify test developer, surveillance panel chairman, and ACC Monitoring Agency. Meeting of TMC, test developer, and surveillance panel required to determine course of action.
  –
- Exceed EWMA industry chart warning limit
  - TMC to notify test developer, surveillance panel chairman, and ACC Monitoring Agency. Coordination of TMC, test developer, and surveillance panel chairman required to discuss potential problem.

20. T-10A LTMS Requirements

The following are the specific T-10A calibration test requirements.

A. Reference Oils and Parameters

The critical parameter is MRV Viscosity. The reference oils required for test stand and test laboratory calibration are reference oils accepted by the ASTM Mack Test Surveillance Panel. The means and standard deviations for the current reference oils for the critical parameter are presented below.

MRV VISCOSITY
Unit of Measure: cP

Reference Oil	Mean	Standard Deviation
820-2	13128	497
820-3	13128	497

B. Acceptance Criteria

2. New Test Stand

- A minimum of one (1) operationally valid calibration test must be conducted on any approved reference oil.

- 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

- The test stand must have been an ASTM TMC calibrated test stand prior to LTMS introduction or have previously been accepted into the system by meeting LTMS calibration requirements.

- 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.

3. Reference Oil Assignment

Once test stands have been accepted into the system, the TMC will assign reference oils for continuing calibration according to the following reference oil mix:

- 100% of the scheduled calibration tests should be conducted on reference oil 820 (PC-9A), or subsequent approved reblends.

4. Control Charts

In Section 1 of the LTMS, the construction of the control charts that constitute the Lubricant Test Monitoring System is outlined. The constants used for the construction of the control charts for the T-10A, and the response necessary in the case of control chart limit alarms, are depicted below.

LUBRICANT TEST MONITORING SYSTEM CONSTANTS

		EWMA Chart				Shewhart Chart	
		LAMBDA		K		K	
Chart Level	Limit Type	Precision	Severity	Precision	Severity	Precision	Severity
Stand	Action	0.3	0.2	1.46	1.80	1.46	1.75
Lab	Warning	0.3	--	1.46	--	--	--
	Action	0.3	0.2	2.33	1.80	1.46	1.75
Industry	Warning	0.2	0.2	1.46	1.80	--	--
	Action	0.2	0.2	2.33	2.58	--	--

The following are the steps that must be taken in the case of exceeding control chart limits. The steps are listed in order of priority, although charts should be studied simultaneously to determine the cause(s) of a problem. In the case of multiple alarms, contact the TMC for guidance.

- Exceed EWMA laboratory chart action limit for severity
  - Calculate laboratory Severity Adjustment (SA) for each parameter that exceeds action limit, using the current laboratory EWMA (Z_i) as follows:

    MRV Viscosity: $SA = (-Z_i) \times (497)$

  - Confirm calculations with the TMC.

The following industry issues are handled by the TMC and do not require individual laboratory action.

- Exceed EWMA industry chart action limit
  - TMC to notify test developer, surveillance panel chairman, and ACC Monitoring Agency. Meeting of the TMC, test developer, and the surveillance panel required to determine course of action.
- Exceed EWMA industry chart warning limit
  - TMC to notify test developer, surveillance panel chairman, and ACC Monitoring Agency. Coordination of TMC, test developer, and surveillance panel chairman required to discuss potential problem.

21. T-11 LTMS Requirements

The following are the specific T-11 calibration test requirements.

A. Reference Oils and Parameters

The critical parameter is Soot at 12.0 cSt Viscosity Increase. Soot at 4.0 cSt Viscosity Increase, Soot at 15.0 cSt Viscosity Increase, and MRV Viscosity are noncritical parameters. The reference oils required for test stand and test laboratory calibration are reference oils accepted by the ASTM Mack Test Surveillance Panel. The mean and standard deviation for the current reference oils for critical and noncritical parameters are presented below.

SOOT @ 4.0 cSt VISCOSITY INCREASE
Unit of Measure: %
NONCRITICAL PARAMETER

Reference Oil	Mean	Standard Deviation
820-3	3.95	0.30
822-1	4.09	0.20
822-2	4.09	0.20

SOOT @ 12.0 cSt VISCOSITY INCREASE
Unit of Measure: %
CRITICAL PARAMETER

Reference Oil	Mean	Standard Deviation
820-3	5.92	0.22
822-1	5.81	0.50
822-2	5.81	0.50

SOOT @ 15.0 cSt VISCOSITY INCREASE
Unit of Measure: %
NONCRITICAL PARAMETER

Reference Oil	Mean	Standard Deviation
820-3	6.51	0.20
822-1	6.48	0.61
822-2	6.48	0.61

MRV VISCOSITY
Unit of Measure: cP
NONCRITICAL PARAMETER

Reference Oil	Mean	Standard Deviation
820-3	14981	916
822-1	13948	584
822-2	13948	584

B. Acceptance Criteria

1. New Test Stand

a. Less than four (4) Operationally Valid Calibration Results in Laboratory

- A minimum of two (2) operationally valid calibration tests with no stand Shewhart severity alarms, must be conducted on any approved reference oil.

- 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.

b. Four (4) or more Operationally Valid Calibration Results in Laboratory*

- The first operationally valid calibration test run on any approved reference oil must have no stand Shewhart severity alarms using the "Reduced K" values. If the first operationally valid calibration test does not meet this acceptance criteria, then the New Test Stand criteria listed above in 1.a must be followed.

* Only test results from calibrated stands in the laboratory count toward the tally of four (4) required operationally valid calibration tests. The fourth test must complete (date and time) before the first test completes (date and time) on a New Test Stand that is seeking calibration with a single test result. In addition, the first test for the stand is to begin within six (6) months of the completion of the last acceptable calibration test.

c. Stand for which a lapse in calibration is not greater than two years.

- The first operationally valid calibration test run on any approved reference oil must have no stand Shewhart severity alarm using the "Reduced K" values. If the first operationally valid calibration test does not meet this acceptance criteria, then the New Test Stand criteria listed above in 1.a must be followed.

2. Existing Test Stand

- The test stand must have been an ASTM TMC calibrated test stand prior to LTMS introduction or have previously been accepted into the system by meeting LTMS calibration requirements.

- All operationally valid calibration tests 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.

3. Reference Oil Assignment

   Once test stands have been accepted into the system, the TMC will assign reference oils for continuing calibration according to the following reference oil mix:

   - 100% of the scheduled calibration tests should be conducted on reference oil 820-3, 822-1 or subsequent approved reblends.

4. Control Charts

   In Section 1, the construction of the control charts that constitute the Lubricant Test Monitoring System is outlined. The constants used for the construction of the control charts for the T-11, and the response necessary in the case of control chart limit alarms, are depicted below.

LUBRICANT TEST MONITORING SYSTEM CONSTANTS

		EWMA Chart				Shewhart Chart	
		LAMBDA		K		K	
Chart Level	Limit Type	Precision	Severity	Precision	Severity	Precision	Severity
Stand	Reduced	--	--	--	--	--	1.43
	Action	0.3	0.3	1.74	2.05	1.74	1.75
Lab	Warning	0.2	--	1.74	--	--	--
	Action	0.2	0.2	2.58	1.96	1.74	1.75
Industry	Warning	0.2	0.2	1.74	2.05	--	--
	Action	0.2	0.2	2.58	2.81	--	--

The following are the steps that must be taken in the case of exceeding control chart limits. The steps are listed in order of priority, although charts should be studied simultaneously to determine the cause(s) of a problem. In the case of multiple alarms, contact the TMC for guidance.

- Exceed EWMA laboratory chart action limit for precision (critical parameter only)

  – Immediately provide written notice of the alarm and its meaning to all Test Purchasers and the TMC. This notice shall be appended to all test reports during the alarm period.

- Exceed EWMA laboratory chart warning limit for precision (critical parameter only)

  – Immediately provide written notice of the alarm and its meaning to all Test Purchasers and the TMC. This notice shall be appended to all test reports during the alarm period.

- Exceed EWMA test stand chart limit for precision (critical parameter only)

  - Immediately provide written notice of the alarm and its meaning to all Test Purchasers and the TMC. This notice shall be appended to all test reports for the stand in question during the alarm period.

- Exceed Shewhart test stand chart limit for precision (critical parameter only)

  - Immediately provide written notice of the alarm and its meaning to all Test Purchasers and the TMC. This notice shall be appended to all test reports for the stand in question during the alarm period.

- Exceed EWMA laboratory chart action limit for severity (all parameters)

  - Calculate laboratory Severity Adjustment (SA) using the current laboratory EWMA (Z_i) as follows:

Soot at 4.0 cSt Viscosity Increase:	$SA = (-Z_i) \times (0.20)$
Soot at 12.0 cSt Viscosity Increase:	$SA = (-Z_i) \times (0.50)$
Soot at 15.0 cSt Viscosity Increase:	$SA = (-Z_i) \times (0.61)$
MRV Viscosity:	$SA = (-Z_i) \times (584)$

  - Confirm calculation with the TMC.

- Exceed EWMA test stand chart limit for severity (critical parameter only)

  - Notify the TMC. If the direction of the test stand severity is deemed different from that of the test laboratory, conduct an additional calibration test in the identified test stand. If this limit is still exceeded after the additional calibration test, then remove test stand from the system, notify the TMC, correct test stand severity problem, and follow requirements for entry of a new test stand into the system.

- Exceed Shewhart test stand chart limit for severity (critical parameter only)

  - Conduct an additional calibration test.

The following industry issues are handled by the TMC and do not require individual laboratory action.

- Exceed EWMA industry chart action limit

  - TMC to notify test developer, surveillance panel chairman, and ACC Monitoring Agency. Meeting of TMC, test developer, and surveillance panel required to determine course of action.

- Exceed EWMA industry chart warning limit

  – TMC to notify test developer, surveillance panel chairman, and ACC Monitoring Agency. Coordination of TMC, test developer, and surveillance panel chairman required to discuss potential problem.

22. T-12 LTMS Requirements

The following are the specific T-12 calibration test requirements.

A. Reference Oils and Parameters

The critical parameters are Cylinder Liner Wear, Top Ring Weight Loss, Oil Consumption, and ΔPb at End of Test. The noncritical parameter is ΔPb 250–300 hours. The reference oils required for test stand and test laboratory calibration are reference oils accepted by the ASTM Mack Test Surveillance Panel. The means and standard deviations for the current reference oils for each critical and noncritical parameter are presented below.

CYLINDER LINER WEAR
Unit of Measure: Micrometres
CRITICAL PARAMETER
NORMAL K VALUE

Reference Oil	Level	Mean	Standard Deviation
821-2	Stand	16.2	3.7
821-2	Lab	15.1	2.8
821-3	Stand	16.2	3.7
821-3	Lab	15.1	2.8
821-4	Stand	16.2	3.7
821-4	Lab	15.1	2.8

TOP RING WEIGHT LOSS
Unit of Measure: Milligrams
CRITICAL PARAMETER
EXPANDED K VALUE

Reference Oil	Mean	Standard Deviation
821-2	62.0	28.2
821-3	62.0	28.2
821-4	62.0	28.2

OIL CONSUMPTION
Unit of Measure: LN(OC grams/hour)
CRITICAL PARAMETER
EXPANDED K VALUE

Reference Oil	Mean	Standard Deviation
821-2	4.0930	0.0790
821-3	4.0930	0.0790
821-4	4.0930	0.0790

ΔPB AT END OF TEST
Unit of Measure: LN(ΔPb ppm)
CRITICAL PARAMETER
NORMAL K VALUE

Reference Oil	Mean	Standard Deviation
821-2	3.1060	0.2420
821-3	3.1060	0.2420
821-4	3.1060	0.2420

ΔPB 250 – 300 HOURS
Unit of Measure: LN(ΔPb 250-300 ppm)
NONCRITICAL PARAMETER
NORMAL K VALUE

Reference Oil	Mean	Standard Deviation
821-2	2.1250	0.3330
821-3	2.1250	0.3330
821-4	2.1250	0.3330

B. Acceptance Criteria

1. New Test Stand

a. First Test Stand in a Laboratory

- A minimum of two (2) operationally valid calibration tests with no stand Shewhart severity alarms (critical parameters only), must be conducted on any approved reference oil.

b. All Subsequent New Test Stands in a Laboratory

- One operationally valid test with no stand Shewhart severity alarms (critical parameters only) must be conducted on any approved reference oil.

2. Existing Test Stand

- The test stand must have been previously accepted into the system by meeting LTMS calibration requirements.

3. Reference Oil Assignment

Once test stands have been accepted into the system, the TMC will assign reference oils for continuing calibration according to the following reference oil mix:

- 100% of the scheduled calibration tests should be conducted on reference oil 821 or subsequent approved reblends.

4. Control Charts

In Section 1 of the LTMS, the construction of the control charts that constitute the Lubricant Test Monitoring System is outlined. The constants used for the construction of the control charts for the T-12, and the response necessary in the case of control chart limit alarms, are depicted below.

LUBRICANT TEST MONITORING SYSTEM CONSTANTS

			EWMA Chart				Shewhart Chart	
			LAMBDA		K		K	
Chart Level	Parameters	Limit Type	Precision	Severity	Precision	Severity	Precision	Severity
Stand	Normal	Action	0.3	0.3	2.10	2.36	2.10	1.80
	Expanded K	Action	0.3	0.3	2.10	2.36	2.10	2.40
Lab	All	Warning	0.3	--	2.10	--	--	--
	Normal	Action	0.3	0.2	2.80	1.96	2.10	1.80
	Expanded K	Action	0.3	0.2	2.80	1.96	2.10	2.40
Industry	All	Warning	0.2	0.2	2.10	2.36	--	--
	All	Action	0.2	0.2	2.80	3.00	--	--

The following are the steps that must be taken in the case of exceeding control chart limits. The steps are listed in order of priority, although charts should be studied simultaneously to determine the cause(s) of a problem. In the case of multiple alarms, contact the TMC for guidance.

- Exceed EWMA laboratory chart action limit for precision (critical parameters only)

- Immediately provide written notice of the alarm and its meaning to all Test Purchasers and the TMC. This notice shall be appended to all test reports during the alarm period.

- Exceed EWMA laboratory chart warning limit for precision (critical parameters only)

  - Immediately provide written notice of the alarm and its meaning to all Test Purchasers and the TMC. This notice shall be appended to all test reports during the alarm period.

- Exceed EWMA test stand chart limit for precision (critical parameters only)

  - Immediately provide written notice of the alarm and its meaning to all Test Purchasers and the TMC. This notice shall be appended to all test reports for the stand in question during the alarm period.

- Exceed Shewhart test stand chart limit for precision (critical parameters only)

  - Immediately provide written notice of the alarm and its meaning to all Test Purchasers and the TMC. This notice shall be appended to all test reports for the stand in question during the alarm period.

- Exceed Shewhart laboratory chart action limit for precision (critical parameters only)

  - Immediately provide written notice of the alarm and its meaning to all Test Purchasers and the TMC. This notice shall be appended to all test reports during the alarm period.

- Exceed EWMA laboratory chart action limit for severity (all parameters)

  - Calculate laboratory Severity Adjustment (SA) for each parameter that exceeds action limit, using the current laboratory EWMA (Z_i) as follows:

Cylinder Liner Wear:	$SA = (-Z_i) \times (1.6)$
Top Ring Weight Loss:	$SA = (-Z_i) \times (24.9)$
Oil Consumption:	$SA = (-Z_i) \times (0.0610)$
ΔPb at End of Test:	$SA = (-Z_i) \times (0.2880)$
ΔPb 250 - 300 Hours:	$SA = (-Z_i) \times (0.3630)$

  - Confirm calculations with the TMC.

- Exceed EWMA test stand chart limit for severity (critical parameters only)

  - Notify the TMC. If the direction of the test stand severity is deemed different from that of the test laboratory, conduct an additional calibration test in the identified test stand. If this limit is still exceeded after the additional calibration test, then remove test stand from the system, notify the TMC, correct test stand severity problem, and follow requirements for entry of a new test stand into the system.

- Exceed Shewhart test stand chart limit for severity (critical parameters only)
  - Conduct an additional calibration test.

The following industry issues are handled by the TMC and do not require individual laboratory action.

- Exceed EWMA industry chart action limit (all parameters)
  - TMC to notify test developer, surveillance panel chairman, and ACC Monitoring Agency. Meeting of the TMC, test developer, and the surveillance panel required to determine course of action.
- Exceed EWMA industry chart warning limit (all parameters)
  - TMC to notify test developer, surveillance panel chairman, and ACC Monitoring Agency. Coordination of TMC, test developer, and surveillance panel chairman required to discuss potential problem.

23. Roller Follower Wear Test LTMS Requirements

The following are the specific Roller Follower Wear Test calibration requirements.

A. Reference Oils and Critical Parameter

The critical parameter is Average Roller Follower Shaft Wear. The reference oils required for test stand and test laboratory calibration are reference oils accepted by the Roller Follower Wear Test Surveillance Panel. The means and standard deviations for the current reference oils for the critical parameter are presented below.

AVERAGE ROLLER FOLLOWER SHAFT WEAR
Unit of Measure: mils

Reference Oil	Mean	Standard Deviation
1004-2	0.33	0.05
1004-3	0.44	0.06
1005-3	0.20	0.05
1005-4	0.20	0.05

B. Acceptance Criteria

1. New Test Stand

   - A minimum of two (2) operationally valid calibration tests with no stand Shewhart severity or precision alarms must be conducted on any approved reference oil.

   - 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

   - The test stand must have previously been accepted into the system by meeting LTMS calibration requirements.

   - All operationally valid calibration test results on reference oils 1004 and 1005, or subsequent approved reblends, 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.

3. Reference Oil Assignment

   Once test stands have been accepted into the system, the TMC will assign reference oils for continuing calibration according to the following reference oil mix:

   - 100% of the scheduled calibration tests should be conducted on reference oils 1004 and 1005 or subsequent approved reblends.

4. Control Charts

   In Section 1, the construction of the control charts that constitute the Lubricant Test Monitoring System is outlined. The constants used for the construction of the control charts for the Roller Follower Wear Test, and the response necessary in the case of control chart limit alarms, are depicted below.

LUBRICANT TEST MONITORING SYSTEM CONSTANTS

		EWMA Chart				Shewhart Chart	
		LAMBDA		K		K	
Chart Level	Limit Type	Precision	Severity	Precision	Severity	Precision	Severity
Stand	Action	0.3	0.2	1.46	1.80	1.46	1.75
Lab	Warning	0.3	--	1.46	--	--	--
	Action	0.3	0.2	2.33	1.80	1.46	1.75
Industry	Warning	0.2	0.2	1.46	1.80	--	--
	Action	0.2	0.2	2.33	2.58	--	--

The following are the steps that must be taken in the case of exceeding control chart limits. The steps are listed in order of priority, although charts should be studied simultaneously to determine the cause(s) of a problem. In the case of multiple alarms, contact the TMC for guidance.

- Exceed EWMA laboratory chart action limit for precision

  – Cease all candidate test starts in the laboratory. Develop plan to correct laboratory precision problem. Coordinate efforts with the TMC.

- Exceed EWMA laboratory chart warning limit for precision

  – Immediately begin two (2) calibration tests on calibrated test stands different from the test stand which exceeded the warning limit. (Calibration tests currently running on "existing" test stands may be used.) If a laboratory has two (2) test stands, conduct one (1) calibration test in each of those two (2) stands. If a laboratory has only one (1) test stand, conduct the two (2) additional calibration tests in that test stand. Notify the TMC for potential laboratory visit. Candidate testing may continue on other calibrated test stands.

- Exceed EWMA test stand chart limit for precision

  – Remove test stand from the system. Notify the TMC. Correct test stand precision problem. Follow requirements for entry of a new test stand into the system.

- Exceed Shewhart test stand chart limit for precision

  – Conduct an additional calibration test.

- Exceed Shewhart laboratory chart action limit for precision

  – Notify the TMC for guidance.

- Exceed EWMA laboratory chart action limit for severity

  – Calculate laboratory Severity Adjustment (SA) for Average Roller Follower Shaft Wear, using the current laboratory EWMA (Z_i) as follows:

    Average Roller Follower Shaft Wear: $SA = (-Z_i) \times (0.04)$

  – Confirm calculation with the TMC.

- Exceed EWMA test stand chart limit for severity

  – Notify the TMC. If the direction of the test stand severity is deemed different from that of the test laboratory, conduct an additional calibration test in the identified test stand. If this limit is still exceeded after the additional calibration test, then remove test stand from the system, notify the TMC, correct test stand severity problem, and follow requirements for entry of a new test stand into the system.

- Exceed Shewhart test stand chart limit for severity

  – Conduct an additional calibration test.

The following industry issues are handled by the TMC and do not require individual laboratory action.

- Exceed EWMA industry chart action limit

  – TMC to notify test developer, surveillance panel chairman, and ACC Monitoring Agency. Meeting of TMC, test developer, and surveillance panel required to determine course of action.

- Exceed EWMA industry chart warning limit

  – TMC to notify test developer, surveillance panel chairman, and ACC Monitoring Agency. Coordination of TMC, test developer, and surveillance panel chairman required to discuss potential problem.

24. Engine Oil Aeration Test LTMS Requirements

The following are the specific Engine Oil Aeration Test calibration requirements.

A. Reference Oils and Critical Parameter

The critical parameter is Average Engine Oil Aeration. The reference oils required for test stand and test laboratory calibration are reference oils accepted by the Engine Oil Aeration Test Surveillance Panel. The means and standard deviations for the current reference oils for the critical parameter are presented below.

AVERAGE ENGINE OIL AERATION
Unit of Measure: %

Reference Oil	Mean	Standard Deviation
1005-3	7.80	0.25
1005-4	7.80	0.25

B. Acceptance Criteria

1. New Test Stand

   - A minimum of two (2) operationally valid calibration tests with no stand Shewhart severity or precision alarms must be conducted on any approved reference oil.

   - 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

   - The test stand must have previously been accepted into the system by meeting LTMS calibration requirements.

   - All operationally valid calibration test results on reference oils 1004 and 1005, or subsequent approved reblends, 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.

3. Reference Oil Assignment

   Once test stands have been accepted into the system, the TMC will assign reference oils for continuing calibration according to the following reference oil mix:

   - 100% of the scheduled calibration tests should be conducted on reference oils 1004 and 1005 or subsequent approved reblends.

4. Control Charts

In Section 1, the construction of the control charts that constitute the Lubricant Test Monitoring System is outlined. The constants used for the construction of the control charts for the Engine Oil Aeration Test, and the response necessary in the case of control chart limit alarms, are depicted below.

LUBRICANT TEST MONITORING SYSTEM CONSTANTS

		EWMA Chart				Shewhart Chart	
		LAMBDA		K		K	
Chart Level	Limit Type	Precision	Severity	Precision	Severity	Precision	Severity
Stand	Warning	0.30	0.30	1.65	--	--	--
	Action	0.30	0.30	2.33	0.00	1.46	1.75
Industry	Warning	0.15	0.15	1.98	2.35	--	--
	Action	0.15	0.15	2.80	3.10	--	--

The following are the steps that must be taken in the case of exceeding control chart limits. The steps are listed in order of priority, although charts should be studied simultaneously to determine the cause(s) of a problem. In the case of multiple alarms, contact the TMC for guidance.

- Exceed EWMA test stand chart action limit for precision
  - Remove test stand from the system. Notify the TMC. Correct test stand precision problem. Follow requirements for entry of a new test stand into the system.
- Exceed EWMA test stand chart warning limit for precision
  - Immediately begin two consecutive calibration tests on the stand which exceeded the warning limit. Notify the TMC.
- Exceed Shewhart test stand chart action limit for precision
  - Conduct an additional calibration test.
- Exceed EWMA stand chart action limit for severity
  - Calculate stand Severity Adjustment (SA) for Average Engine Oil Aeration, using the current stand EWMA (Z_i) as follows:

    Average Engine Oil Aeration: $SA = (-Z_i) \times (0.25)$

  - Confirm calculation with the TMC.

- Exceed Shewhart test stand chart action limit for severity
  - Conduct an additional calibration test.

The following industry issues are handled by the TMC and do not require individual laboratory action.

- Exceed EWMA industry chart action limit
  - TMC to notify test developer and surveillance panel chairman. Meeting of TMC, test developer, and surveillance panel required to determine course of action.
- Exceed EWMA industry chart warning limit
  - TMC to notify test developer, surveillance panel chairman. Coordination of TMC, test developer, and surveillance panel chairman required to discuss potential problem.

25. T-12A

The following are the specific T-12A calibration requirements.

A. Reference Oils and Critical Parameter

The critical parameter is MRV Viscosity. The reference oils required for test stand and test laboratory calibration are reference oils accepted by the ASTM Mack Test Surveillance Panel. The means and standard deviations for the current reference oils for the critical parameter are presented below.

MRV VISCOSITY
Unit of Measure: cP

Reference Oil	Mean	Standard Deviation
821-3	11736	331
821-4	11736	331

B. Acceptance Criteria

1. New Test Stand

- A minimum of one (1) operationally valid calibration test must be conducted on any approved reference oil.

- 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

- The test stand must have been an ASTM TMC calibrated test stand prior to LTMS introduction or have previously been accepted into the system by meeting LTMS calibration requirements.

- 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.

3. Reference Oil Assignment

Once test stands have been accepted into the system, the TMC will assign reference oils for continuing calibration according to the following reference oil mix:

- 100% of the scheduled calibration tests should be conducted on reference oils 821-1 or subsequent approved reblends.

4. Control Charts

In Section 1, the construction of the control charts that constitute the Lubricant Test Monitoring System is outlined. The constants used for the construction of the control charts for the T-12A, and the response necessary in the case of control chart limit alarms, are depicted below.

LUBRICANT TEST MONITORING SYSTEM CONSTANTS

		EWMA Chart				Shewhart Chart	
		LAMBDA		K		K	
Chart Level	Limit Type	Precision	Severity	Precision	Severity	Precision	Severity
Stand	Action	0.30	0.30	2.10	2.36	2.10	1.80
Lab	Warning	0.30	--	2.10	--	--	--
	Action	0.30	0.20	2.80	1.96	2.10	1.80
Industry	Warning	0.20	0.20	2.10	2.36	--	--
	Action	0.20	0.20	2.80	3.00	--	--

The following are the steps that must be taken in the case of exceeding control chart limits. The steps are listed in order of priority, although charts should be studied simultaneously to determine the cause(s) of a problem. In the case of multiple alarms, contact the TMC for guidance.

- Exceed EWMA stand chart action limit for severity

  – Calculate stand Severity Adjustment (SA) for MRV Viscosity, using the current stand EWMA (Z_i) as follows:

    MRV Viscosity: $SA = (-Z_i) \times (331^*)$

  * Based on a non-pooled standard deviation of 14 T-12 test results using 821 & 821-1 run during T-12A development.

  – Confirm calculation with the TMC.

The following industry issues are handled by the TMC and do not require individual laboratory action.

- Exceed EWMA industry chart action limit

  – TMC to notify test developer, surveillance panel chairman, and ACC Monitoring Agency. Meeting of TMC, test developer, and surveillance panel required to determine course of action.

- Exceed EWMA industry chart warning limit

  – TMC to notify test developer, surveillance panel chairman, and ACC Monitoring Agency. Meeting of TMC, test developer, and surveillance panel required to determine course of action.

26. 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

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

   - The test stand must have been an ASTM TMC calibrated test stand prior to LTMS introduction or have previously been accepted into the system by meeting LTMS calibration requirements.

   - 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.

3. Reference Oil Assignment

   Once test stands have been accepted into the system, the TMC will assign reference oils for continuing calibration according to the following reference oil mix:

   - 50% of the scheduled calibration tests should be conducted on reference oil 123 or subsequent approved reblends.
   - 50% of the scheduled calibration tests should be conducted on reference oil 151-3 or 155 or subsequent approved reblends.

4. Control Charts

   In Section 1, the construction of the control charts that constitute the Lubricant Test Monitoring System is outlined. The constants used for the construction of the control charts for the L-33-1, and the response necessary in the case of control chart limit alarms, are depicted below.

LUBRICANT TEST MONITORING SYSTEM CONSTANTS

		EWMA Chart				Shewhart Chart	
		LAMBDA		K		K	
Chart Level	Limit Type	Precision	Severity	Precision	Severity	Precision	Severity
Stand	Warning	0.30	0.30	1.65	--	--	--
	Action	0.30	0.30	2.33	1.96	1.46	1.80
Lab	Action	--	0.20	--	1.80	--	--
Industry	Warning	0.20	0.20	1.46	1.80	--	--
	Action	0.20	0.20	2.33	2.58	--	--

The following are the steps that must be taken in the case of exceeding control chart limits.

- Exceed EWMA test stand chart action limit for precision
  - Remove test stand from the system. Notify the TMC. Correct test stand precision problem. Follow requirements for entry of a new test stand into the system.
- Exceed EWMA test stand chart warning limit for precision
  - Immediately begin two calibration tests on the test stand.
- Exceed Shewhart test stand chart limit for precision
  - Conduct an additional calibration test.

- Exceed EWMA test stand chart action limit for severity

  - Calculate test stand Severity Adjustment (SA) for Final Rust, using the current test stand EWMA (Z_i) as follows:

    Final Rust: $SA = (-Z_i) \times (0.25)$

  - Confirm calculations with the TMC.

- Exceed Shewhart test stand chart limit for severity

  - Conduct an additional calibration test.

The following industry issues are handled by the TMC and do not require individual laboratory action.

- Exceed EWMA industry chart action limit.

  - TMC to notify surveillance panel chairman. Meeting of TMC and the surveillance panel required to determine course of action.

- Exceed EWMA industry chart warning limit

  - TMC to notify surveillance panel chairman. Coordination of TMC and the surveillance panel chairman required to discuss potential problem.

27. L-37 LTMS Requirements

The following are the specific L-37 calibration test requirements.

A. Reference Oils and Parameters

The critical parameters are Pinion Ridging, Pinion Rippling, Pinion Pitting/Spalling, Pinion Wear, and Pinion Scoring. The reference oils required for test stand and test laboratory calibration are reference oils accepted by the ASTM L-37 Surveillance Panel. The means and standard deviations for the current reference oils for each critical parameter are presented below.

RIDGING
Unit of Measure: Merits

Hardware	Pinion Batch	Reference Oil	Mean	Standard Dev.	Acceptance Band
LUBRITED	L247/T758A	128-1	7.40	0.516	6 - 8
		151-3	8.80	0.422	8 - 10
		155	9.00	0.000	9 - 9
	V1L686/P4L626A	128-1	6.35	0.813	5 - 8
		151-3	6.43	1.207	4 - 9
		152	5.25	0.500	4 - 6
		153	5.00	0.000	5 - 5
		155	7.00	0.000	7 - 7
	V1L528/P4T883A	134	7.00	1.155	4 - 10
		152-1	8.00	0.632	7 - 10
		152-2	8.00	0.632	7 - 10
		155	8.29	0.488	7 - 10
NONLUBRITED	V1L417/P4L792	151-3	9.47	0.507	9 - 10
		152	9.17	0.408	8 - 10
		152-1	9.47	0.640	8 - 10
		153	9.00	0.816	8 - 10
		153-1	8.80	0.616	8 - 10
		155	9.50	0.527	9 - 10
	V1L500/P4T813	152-1	8.85	0.689	8 - 10
		155	9.07	0.594	8 - 10
	V1L528/P4T883A	134	6.40	1.673	3 - 9
		152-1	8.75	0.707	7 - 10
		152-2	8.75	0.707	7 - 10
		155	8.56	0.882	7 - 10

RIPPLING
Unit of Measure: Merits

Hardware	Pinion Batch	Reference Oil	Mean	Standard Dev.	Acceptance Band
LUBRITED	L247/T758A	128-1	7.60	1.075	6 - 10
		151-3	8.60	0.516	8 - 10
		155	8.00	0.000	8 - 8
	V1L686/P4L626A	128-1	7.20	1.473	5 - 10
		151-3	8.71	0.463	8 - 10
		152	8.25	0.500	7 - 9
		153	8.00	0.000	8 - 8
		155	9.00	0.000	9 - 9
	V1L528/P4T883A	134	7.00	1.414	4 - 10
		152-1	8.83	0.753	7 - 10
		152-2	8.83	0.753	7 - 10
		155	8.86	0.690	7 - 10
NONLUBRITED	V1L417/P4L792	151-3	9.33	0.606	8 - 10
		152	9.17	0.408	8 - 10
		152-1	9.40	0.507	8 - 10
		153	8.25	0.500	7 - 9
		153-1	8.90	0.447	8 - 10
		155	9.60	0.516	9 - 10
	V1L500/P4T813	152-1	9.39	0.506	8 - 10
		155	9.33	0.488	8 - 10
	V1L528/P4T883A	134	8.40	0.894	6 - 10
		152-1	8.63	0.916	7 - 10
		152-2	8.63	0.916	7 - 10
		155	8.44	1.014	6 - 10

PITTING/SPALLING
Unit of Measure: Merits

Hardware	Pinion Batch	Reference Oil	Mean	Standard Dev.	Acceptance Band
LUBRITED	L247/T758A	128-1	9.02	0.892	7 - 10
		151-3	9.49	0.586	8 - 10
		155	9.30	0.000	9.3 - 9.3
	V1L686/P4L626A	128-1	9.77	0.421	9 - 10
		151-3	9.68	0.632	9 - 10
		152	9.53	0.359	9 - 10
		153	9.30	0.424	9 - 10
		155	9.90	0.000	9.9 - 9.9
	V1L528/P4T883A	134	8.83	0.974	7 - 10
		152-1	9.88	0.041	9.3 - 10
		152-2	9.88	0.041	9.3 - 10
		155	9.90	0.436	9 - 10
NONLUBRITED	V1L417/P4L792	151-3	9.71	1.080	8 - 10
		152	9.90	0.000	9.9 - 9.9
		152-1	9.44	1.782	6 - 10
		153	9.88	0.050	9.8 - 10
		153-1	9.89	0.049	9.8 - 10
		155	9.90	0.040	9.8 - 10
	V1L500/P4T813	152-1	9.89	0.028	9.8 - 9.9
		155	9.84	0.124	9.6 - 10
	V1L528/P4T883A	134	3.80	1.483	1 - 7
		152-1	9.45	1.003	7 - 10
		152-2	9.45	1.003	7 - 10
		155	8.70	1.578	5 - 10

WEAR
Unit of Measure: Merits

Hardware	Pinion Batch	Reference Oil	Mean	Standard Dev.	Acceptance Band
LUBRITED	L247/T758A	128-1	5.80	0.422	5 - 7
		151-3	6.00	0.000	6 - 6
		155	6.00	0.000	6 - 6
	V1L686/P4L626A	128-1	6.40	0.598	5 - 7
		151-3	6.57	0.598	5 - 8
		152	6.25	0.500	5 - 7
		153	5.50	0.707	4 - 7
		155	7.00	0.000	7 - 7
	V1L528/P4T883A	134	6.00	0.242	5 - 7
		152-1	7.00	0.242	6 - 8
		152-2	7.00	0.242	6 - 8
		155	6.86	0.378	6 - 8
NONLUBRITED	V1L417/P4L792	151-3	8.00	0.587	7 - 9
		152	8.00	0.632	7 - 9
		152-1	8.00	0.378	7 - 9
		153	7.50	0.577	6 - 9
		153-1	7.55	0.605	6 - 9
		155	8.00	0.289	7 - 9
	V1L500/P4T813	152-1	7.46	0.519	7 - 8
		155	7.47	0.516	7 - 8
	V1L528/P4T883A	134	5.60	0.894	4 - 8
		152-1	7.00	0.500	6 - 8
		152-2	7.00	0.500	6 - 8
		155	6.78	0.441	6 - 8

SCORING
Non-lubrited & Lubrited Test Hardware
Unit of Measure: Merits

At the present time, no targets are available for Scoring. As a result, Pinion Scoring cannot be charted. However, the TMC will monitor the reporting of scoring values for results that are different from 10.00 and report occurrences to the surveillance panel. Any reference oil test exhibiting Pinion Scoring less than 10.00 is unacceptable for calibration.

B. Acceptance Criteria

1. New Stand

- A minimum of three (3) operationally valid calibration tests must be conducted with results falling within the acceptance bands. Two of the three tests are to be conducted on either non-lubrited or lubrited hardware (laboratory choice). The remaining test is to be conducted on the other type of hardware.

- Reference oil assignment is dependent on hardware and gear batch selection by the laboratory. See Section 3 below for approved gear batches and oil assignments.

- 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. Note that non-lubrited and lubrited hardware test results are charted separately.

2. Existing Test Stand

- The test stand must have previously been accepted into the system by meeting LTMS calibration requirements.

- All operationally valid calibration test results on approved hardware and reference oils, as outlined in Section 3 below, 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. Note that non-lubrited and lubrited hardware test results are charted separately.

- Alternate lubrited and non-lubrited hardware with each reference oil calibration sequence.

3. Reference Oil Assignment

Once test stands have been accepted into the system, the TMC will assign reference oils for continuing calibration according to the following reference oil mix:

Test Hardware	Pinion/Ring Batch	Reference Oil	Assignment Frequency
Lubrited	C1L308/P4L309R	128-1	100%
		128-2	
	C1L426/P4L404A	128-1	100%
		128-2	
	V1L303/P4L514A	128-1	100%
		128-2	
	V1L686/P4L626A	128-1	25%
		128-2	
		155	25%
		152	25%
		153	25%
	L247/T758A	128-1	33.3%
		128-2	33.3%
		155	33.3%
	V1L528/P4T883A	134	20%
		152-1 or -2	40%
		155	40%
Non-Lubrited	C1L308/P4L318R	128-1	100%
		128-2	
	C1L426/P4L415A	128-1	100%
		128-2	
	V1L303/P4L514A	128-1	100%
		128-2	
	V1L686/P4L626A	128-1	50%
		128-2	
		155	50%
		155	
	V1L176/P4L741A	128-1	50%
		128-2	
		155	50%
	V1L351/P4T771	155	50%
		152	25%
		153	25%
	V1L417/P4L792	155	50%
		152	25%
		153	25%
	V1L500/P4T813	152-1	25%
		153-1	25%
		155	50%
	V1L528/P4T883A	134	20%
		152-1 or -2	40%
		155	40%

4. Control Charts.

In Section 1, the construction of the control charts that constitute the Lubricant Test Monitoring System is outlined. The constants used for the construction of the control charts for the L-37, and the response necessary in the case of control chart limit alarms, are depicted below. Note that control charting all critical parameters is required.

LUBRICANT TEST MONITORING SYSTEM CONSTANTS

		EWMA Chart				Shewhart Chart	
		LAMBDA		K		K	
Chart Level	Limit Type	Precision	Severity	Precision	Severity	Precision	Severity
Stand	Warning	0.2	--	2.24	--	--	1.80
	Action	0.2	0.2	2.81	1.96	2.10	1.80
Lab	Action	0.2	0.2	2.81	3.03	--	1.80
Industry	Warning	0.2	0.2	2.24	2.49	--	--
	Action	0.2	0.2	2.88	3.03	--	--

The following are the steps that must be taken in the case of exceeding control chart limits.

- Exceed EWMA test stand chart action limit for precision
  - Remove test stand from the system. Notify the TMC. Correct test stand precision problem. Follow requirements for entry of a new test stand into the system.
- Exceed EWMA test stand chart warning limit for precision
  - Immediately begin two calibration tests on the test stand.
- Exceed Shewhart test stand chart limit for precision
  - Conduct an additional calibration test.
- Exceed EWMA laboratory chart limit for precision or severity
  - Notify the TMC for guidance.

- Exceed EWMA test stand chart action limit for severity

  – Calculate test stand Severity Adjustment (SA) for each parameter that exceeds action limit, using the current test stand EWMA (Z_i) as follows:

  Non-lubrited Test Hardware:

Ridging:	$SA = (-Z_i) \times (0.666)$
Rippling:	$SA = (-Z_i) \times (0.557)$
Pitting/Spalling:	$SA = (-Z_i) \times (0.847)$
Wear:	$SA = (-Z_i) \times (0.713)$

  Lubrited Test Hardware:

Ridging:	$SA = (-Z_i) \times (1.430)$
Rippling:	$SA = (-Z_i) \times (0.476)$
Pitting/Spalling:	$SA = (-Z_i) \times (0.579)$
Wear:	$SA = (-Z_i) \times (0.519)$

Confirm calculations with the TMC.

  – SA calculations are for information purposes only.

- Result outside acceptance band

  – Conduct an additional calibration test.

The following industry issues are handled by the TMC and do not require individual laboratory action.

- Exceed EWMA industry chart action limit

  – TMC to notify surveillance panel chairman. Meeting of the TMC and the surveillance panel required to determine course of action.

- Exceed EWMA industry chart warning limit

  – TMC to notify surveillance panel chairman. Coordination of TMC and surveillance panel required to discuss potential problem.

28. L-42 LTMS Requirements

The following are the specific L-42 calibration test requirements.

A. Reference Oils and Critical Parameter

The critical parameter is Coast Side Pinion Scoring. The reference oils required for test stand and test laboratory calibration are the reference oils accepted by the ASTM L-42 Surveillance Panel. The means and standard deviations for the current reference oils, by gear batch, for the critical parameter are presented below.

COAST SIDE PINION SCORING
Unit of Measure: % Scoring
Gear Batch P8L123

Reference Oil	Mean	Standard Deviation
114-1	23.2	8.06
115	23.2	8.06
116	22.9	4.81
116-1	22.9	4.81

COAST SIDE PINION SCORING
Unit of Measure: % Scoring
Gear Batch P8L205

Reference Oil	Mean	Standard Deviation
114-1	23.4	5.27
115	23.4	5.27
116	22.9	4.81
116-1	22.9	4.81

COAST SIDE PINION SCORING
Unit of Measure: % Scoring
Gear Batch P8L327

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 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

B. Acceptance Criteria

1. New Test Stand

- A minimum of four (4) operationally valid calibration tests, with no stand Shewhart severity alarms, must be conducted. Three (3) tests must be conducted on reference oil 114, 115, 116, 117 or subsequent approved reblends. All three tests must be completed on the same reference oil. The remaining one (1) calibration test must be conducted on discrimination reference oil 112, 113 or subsequent approved reblends. The end of test coast side pinion scoring value of the discrimination oil must be a minimum of twice the average value of the preceding three (3) acceptable reference oil tests. If a second discrimination oil test is needed, the test, if acceptable, will count as one (1) of the 15 non-reference oil tests. In the event that neither discrimination oil test meets the above

requirement, a complete new calibration sequence must be performed. The results from tests conducted on discrimination oils are not charted.

- 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

- The test stand must have been an ASTM TMC calibrated test stand prior to LTMS introduction or previously accepted into the system by meeting LTMS calibration requirements.

- A test stand must complete three (3) operationally valid calibration tests, with no stand Shewhart severity alarms, on reference oil 114, 115, 116, or subsequent approved reblends. All three tests must be completed on the same reference oil. Every six months or fourth calibration sequence, an additional test must be conducted on discrimination reference oil 112, 113 or subsequent approved reblends. The end of test coast side pinion scoring value of the discrimination oil must be a minimum of twice the average value of the preceding three (3) acceptable reference oil tests. If a second discrimination oil test is needed, the test, if acceptable, will count as one (1) of the 15 non-reference oil tests. In the event that neither discrimination oil test meets the above requirement, a complete new calibration sequence must be performed. The results from tests conducted on discrimination oils are not charted.

3. Reference Oil Assignment

Once test stands have been accepted into the system, the TMC will assign reference oils for continuing calibration according to the following reference oil mix:

Gear Batch	Oil Assignments
P8L123	Assign either three 116, three 115, or three 114 oils (or subsequent reblend). Every 6 months or fourth calibration sequence, also assign one discrimination oil 112.
P8L119	Assign three 116 oils (or subsequent reblend). Every 6 months or fourth calibration sequence, also assign one discrimination oil 112 or 113.
P8L205	Assign either three 116, three 115, or three 114 oils (or subsequent reblend). Every 6 months or fourth calibration sequence, also assign one discrimination oil 112.
P8L737	Assign either three 115 or three 114 oils (or subsequent reblend). Every 6 months or fourth calibration sequence, also assign one discrimination oil 112.
P8L327	Assign either three 116 or three 115 oils (or subsequent reblend). Every 6 months or fourth calibration sequence, also assign one discrimination oil 112.
P8L604	Assign either three 116 or three 115 oils (or subsequent reblend). Every 6 months or fourth calibration sequence, also assign one discrimination oil 112.
P4L806	Assign three 116 oils (or subsequent reblend). Every 6 months or fourth calibration sequence, also assign one discrimination oil 112, 113 or

	subsequent reblends.
P8T025A	Assign three 116 or 117 oils (or subsequent reblend). Every 6 months or fourth calibration sequence, also assign one discrimination oil 112, 113 or subsequent reblends.

Note: See Sections 1 & 2 above for more details on oil assignments.

4. Control Charts

In Section 1, the construction of the control charts that constitute the Lubricant Test Monitoring System is outlined. The constants used for the construction of the control charts for the L-42, and the response necessary in the case of control chart limit alarms, are depicted below.

LUBRICANT TEST MONITORING SYSTEM CONSTANTS

		EWMA Chart				Shewhart Chart	
		LAMBDA		K		K	
Chart Level	Limit Type	Precision	Severity	Precision	Severity	Precision	Severity
Stand	Warning	--	--	--	--	--	--
	Action	--	--	-	--	--	1.80
Lab	Action	--	--	--	--	--	--
Industry	Warning	0.2	0.2	2.19	2.45	--	--
	Action	0.2	0.2	2.88	3.08	--	--

The following are the steps that must be taken in the case of exceeding control chart limits.

- Exceed Shewhart test stand chart limit for severity
  - Conduct an additional calibration test.

The following industry issues are handled by the TMC and do not require individual laboratory action.

- Exceed EWMA industry chart action limit
  - TMC to notify surveillance panel chairman. Meeting of TMC and the surveillance panel required to determine course of action.
- Exceed EWMA industry chart warning limit
  - TMC to notify surveillance panel chairman. Coordination of TMC and the surveillance panel chairman is required to discuss potential problem.

29. L-60-1 LTMS Requirements

The following are the specific L-60-1 calibration test requirements.

A. Reference Oils and Parameters

The critical parameters are Viscosity Increase, Pentane Insolubles, Average Carbon/Varnish, and Average Sludge. The reference oils required for test stand and test laboratory calibration are reference oils accepted by the ASTM L-60-1 Surveillance Panel. The means and standard deviations for the current reference oils for each critical and noncritical parameter are presented below.

VISCOSITY INCREASE
Unit of Measure: LN(VISI)
CRITICAL PARAMETER

Reference Oil	Mean	Standard Deviation
131-3	4.40	0.20
131-4	4.33	0.17
148-1	3.61	0.15
151-2	3.62	0.15

PENTANE INSOLUBLES
Unit of Measure: LN(PEN)
CRITICAL PARAMETER

Reference Oil	Mean	Standard Deviation
131-3	0.83	0.73
131-4	0.94	0.31
148-1	-0.95	0.39
151-2	0.75	0.37

AVERAGE CARBON/VARNISH
Unit of Measure: LN(ACV/(10-ACV))
CRITICAL PARAMETER

Reference Oil	Mean	Standard Deviation
131-3	-2.08	0.42
131-4	-2.14	0.32
148-1	1.59	0.47
151-2	1.81	0.40

AVERAGE SLUDGE
Unit of Measure: -LN(10 - ASL)
CRITICAL PARAMETER

Reference Oil	Mean	Standard Deviation
131-3	0.53	0.49
131-4	0.66	0.35
148-1	0.76	0.19
151-2	0.54	0.23

TOLUENE INSOLUBLES
Unit of Measure: LN(TOL)
NONCRITICAL PARAMETER

Reference Oil	Mean	Standard Deviation
131-3	-0.59	0.75
131-4	-0.08	0.41
148-1	-1.36	0.49
151-2	0.26	0.50

B. Acceptance Criteria

1. New Test Stand

- A minimum of two (2) operationally valid calibration tests, with no stand Shewhart severity alarms (all parameters) and no stand Shewhart precision alarms (critical parameters only), 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

- The test stand must have been an ASTM TMC calibrated test stand prior to LTMS introduction or have previously been accepted into the system by meeting LTMS calibration requirements.

- 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.

3. Reference Oil Assignment

Once test stands have been accepted into the system, the TMC will assign reference oils for continuing calibration according to the following reference oil mix:

- 100% of the scheduled calibration tests should be conducted on reference oils 148 and 151-2, or subsequent approved reblends.

- Oil 131-3 or 131-4 should be assigned, as needed, for investigation of test stand problems.

4. Control Charts

In Section 1 of the LTMS, the construction of the control charts that constitute the Lubricant Test Monitoring System is outlined. The constants used for the construction of the control charts for the L-60-1, and the response necessary in the case of control chart limit alarms, are depicted below.

LUBRICANT TEST MONITORING SYSTEM CONSTANTS

		EWMA Chart				Shewhart Chart	
		LAMBDA		K		K	
Chart Level	Limit Type	Precision	Severity	Precision	Severity	Precision	Severity
Stand	Warning	0.2	--	2.235	--	--	--
	Action	0.2	0.2	2.81	1.96	2.10	1.80
Lab	Action	0.2	0.2	2.81	3.03	--	1.80
Industry	Warning	0.15	0.15	2.235	2.49	--	--
	Action	0.15	0.15	2.81	3.03	--	--

The following are the steps that must be taken in the case of exceeding control chart limits. The steps are listed in order of priority, although charts should be studied simultaneously to determine the cause(s) of a problem. In the case of multiple alarms, contact the TMC for guidance.

- Exceed EWMA test stand chart action limit for precision (critical parameters only)

  – Remove test stand from the system. Notify the TMC. Correct test stand precision problem. Follow requirements for entry of a new test stand into the system.

- Exceed EWMA test stand chart warning limit for precision (critical parameters only)

  – Immediately begin two calibration tests on the test stand.

- Exceed Shewhart test stand chart limit for precision (critical parameters only)

  – Conduct an additional calibration test.

- Exceed EWMA laboratory chart limit for precision or severity (all parameters)

  - Notify the TMC for guidance.

- Exceed EWMA test stand chart action limit for severity (all parameters)

  - Calculate test stand Severity Adjustment (SA) for each parameter that exceeds action limit, using the current test stand EWMA (Z_i) as follows:

Viscosity Increase:	$SA = (-Z_i) \times (0.08)$
Pentane Insolubles:	$SA = (-Z_i) \times (0.20)$
Toluene Insolubles:	$SA = (-Z_i) \times (0.34)$
Average Carbon/Varnish:	$SA = (-Z_i) \times (0.44)$
Average Sludge:	$SA = (-Z_i) \times (0.16)$

  - Confirm calculations with the TMC.

- Exceed Shewhart test stand chart limit for severity (all parameters)

  - Conduct an additional calibration test.

The following industry issues are handled by the TMC and do not require individual laboratory action.

- Exceed EWMA industry chart action limit (all parameters)

  - TMC to notify surveillance panel chairman. Meeting of the TMC and the surveillance panel required to determine course of action.

- Exceed EWMA industry chart warning limit (all parameters)

  - TMC to notify surveillance panel chairman. Coordination of TMC and surveillance panel required to discuss potential problem.

30. High Temperature Cyclic Durability Test LTMS Requirements

The following are the specific High Temperature Cyclic Durability calibration test requirements.

A. Reference Oils and Critical Parameter

The critical parameter is Cycles to Unsychronized Shifts. The reference oils required for test stand and test laboratory calibration are the reference oils accepted by the ASTM High Temperature Cyclic Durability Test Surveillance Panel. The means and standard deviations for the current reference oils for the critical parameter are presented below.

CYCLES TO UNSYCHRONIZED SHIFTS
Unit of Measure: Cycles

Reference Oil	Mean	Standard Deviation
150-2	24271	4623
151-3	74489	9662
154	24271	4623
155	74489	9662
155-1	65963	15022

B. Acceptance Criteria

1. New Test Stand

- A minimum of three (3) operationally valid calibration tests, with no stand Shewhart severity alarms, must be conducted. Two (2) tests must be conducted on reference oils 151 or 155 or subsequent approved reblends, and one (1) test must be conducted on reference oil 150 or 154 or subsequent approved reblends.

2. Existing Test Stand

- The test stand must have been TMC calibrated prior to LTMS introduction or previously accepted into the system by meeting LTMS calibration requirements.

- A test stand must complete one test on reference oil 151 or 155, or subsequent approved reblends, with no stand Shewhart severity alarm.

3. Reference Oil Assignment

Once test stands have been accepted into the system, the TMC will assign reference oils for continuing calibration according to the following reference oil mix:

- 100% of the scheduled calibration tests should be conducted on reference oils 150, 151, and 155, or subsequent approved reblends.

- See Sections 1 and 2 above for detailed oil assignment instructions.

4. Control Charts

In Section 1, the construction of the control charts that constitute the Lubricant Test Monitoring System is outlined. The constants used for the construction of the control charts for the High Temperature Cyclic Durability Test, and the response necessary in the case of control limit alarms, are depicted below.

LUBRICANT TEST MONITORING SYSTEM CONSTANTS

		EWMA				Shewhart Chart	
		LAMBDA		K		K	
Chart Level	Limit Type	Precision	Severity	Precision	Severity	Precision	Severity
Stand	Action	--	--	--	--	--	1.96
Industry	Warning	0.2	0.3	1.46	1.80	--	--
	Action	0.2	0.3	2.33	2.58	--	--

The following are the steps that must be taken in the case of exceeding control chart limits.

- Exceed Shewhart test stand chart limit for severity (all parameters)

– For reference oils 151 and 155 or subsequent reblends, conduct an additional calibration test.

– For reference oil 150 and 154 or subsequent reblends, conduct an additional calibration test only if the test exceeds the Shewhart limit in the mild direction.

The following industry issues are handled by the TMC and do not require individual laboratory action.

- Exceed EWMA industry chart action limit

  – TMC to notify test developer and surveillance panel chairman. Meeting of TMC, test developer, and surveillance panel chairman required to determine course of action.

- Exceed EWMA industry chart warning limit

  - TMC to notify test developer and surveillance panel chairman. Coordination of TMC, test developer, and surveillance panel chairman required to discuss potential problem.

31. Oil Seal Compatibility Test LTMS Requirements

The following are the specific Oil Seal Compatibility Test calibration test requirements.

A. Reference Oils and Critical Parameters

The critical parameters are Elongation, Shore Hardness, and Volume Change. The reference oils required for test stand and test laboratory calibration are the reference oils accepted by the ASTM Oil Seal Compatibility Test Surveillance Panel. The means and standard deviations for the current reference oils for the critical parameters are presented below.

ELONGATION
Unit of Measure: Percent

Reference Oil	Elastomer	Mean	Standard Deviation
160-1	Polyacrylate	23.04	14.289
160-1	Fluoroelastomer	-47.65	5.506
161-1	Polyacrylate	68.88	17.850
161-1	Fluoroelastomer	-34.57	6.989
161-1	Nitrile	10.43	10.691
162	Nitrile	-65.35	7.330
168	Nitrile	-74.52	6.965
169	Polyacrylate	49.2	21.82
169	Fluoroelastomer	-39.5	6.99
169	Nitrile	-16.2	10.69

SHORE HARDNESS
Unit of Measure: Points

Reference Oil	Elastomer	Mean	Standard Deviation
160-1	Polyacrylate	-1.8	1.16
160-1	Fluoroelastomer	1.6	1.36
161-1	Polyacrylate	-24.9	2.83
161-1	Fluoroelastomer	1.6	1.30
161-1	Nitrile	-16.1	2.18
162	Nitrile	2.0	2.03
168	Nitrile	3.0	1.89
169	Polyacrylate	-16.0	2.83
169	Fluoroelastomer	0.1	1.30
169	Nitrile	-8.6	2.18

VOLUME CHANGE
Unit of Measure: Percent

Reference Oil	Elastomer	Mean	Standard Deviation
160-1	Polyacrylate	0.343	0.4473
160-1	Fluoroelastomer	2.053	0.4075
161-1	Polyacrylate	19.624	1.4348
161-1	Fluoroelastomer	6.199	0.7080
161-1	Nitrile	18.444	1.7057
162	Nitrile	2.460	1.5821
168	Nitrile	1.326	1.4730
169	Polyacrylate	13.1	1.43
169	Fluoroelastomer	4.4	0.71
169	Nitrile	11.8	1.71

B. Acceptance Criteria

1. New Test Stand

   - For each elastomer type, an operationally valid calibration test, with no Shewhart severity alarms, must be conducted on each of the two approved reference oils.

2. Existing Test Stand

   - The test stand must have been TMC calibrated prior to LTMS introduction or previously accepted into the system by meeting LTMS calibration requirements.

3. Reference Oil Assignment

   Once test stands have been accepted into the system, the TMC will assign reference oils for continuing calibration according to the following reference oil mix:

Elastomer Type	Oil Assignments
PA	Assign reference oils 160, 161 or 169 (or subsequent reblends) for every calibration sequence.
FL	Assign reference oils 160, 161 or 169 (or subsequent reblends) for every calibration sequence.
NI	Assign reference oils 161, 162, or 168 (or subsequent reblends) for every calibration sequence.

4. Control Charts

In Section 1, the construction of the control charts that constitute the Lubricant Test Monitoring System is outlined. The constants used for the construction of the control charts for the Oil Seal Compatibility Test, and the response necessary in the case of control chart limit alarms, are depicted below.

LUBRICANT TEST MONITORING SYSTEM CONSTANTS

		EWMA Chart				Shewhart Chart	
		LAMBDA		K		K	
Chart Level	Limit Type	Precision	Severity	Precision	Severity	Precision	Severity
Stand	Action	--	--	--	--	--	2.20
Lab	Warning	--	--	--	--	--	--
	Action	--	--	--	--	--	--
Industry	Warning	0.15	0.15	2.24	2.49	--	--
	Action	0.15	0.15	2.88	3.03	--	--

The following are steps that must be taken in the case of exceeding control chart limits.

- Exceed test stand chart limit for severity (all parameters)
  - For each failed elastomer type, conduct an additional calibration test.

The following industry issues are handled by the TMC and do not require individual laboratory action.

- Exceed EWMA industry chart action limit (all parameters)
  - TMC to notify surveillance panel chairman. Meeting of TMC and surveillance panel chairman required to determine course of action.
- Exceed EWMA industry chart warning limit (all parameters)
  - TMC to notify surveillance panel chairman. Coordination of TMC and surveillance panel chairman required to discuss potential problem.

APPENDIX A

HISTORY OF LTMS REFERENCE OIL MEANS AND STANDARD DEVIATIONS

Sequence IIIF Reference Oil Targets														
Oil	n	Effective Dates		VIS80[3]		HRS		APV		WPD		SACLW	VIS60[4]	
		From[1]	To[2]	$\overline{X}$	s	$\overline{X}$	s	$\overline{X}$	s	$\overline{X}$	s	Maximum	$\overline{X}$	s
1006	6	6-10-00	11-14-01	0.0156989	0.0076717	- -	- -	9.14	0.263	3.29	0.284	20.0	- -	- -
	34	11-15-01	11-30-01	0.0156989	0.0076717	- -	- -	9.14	0.263	3.29	0.284	20.0	5.41732	0.230855
	35	12-1-01	8-1-03	0.0167362	0.0086503	- -	- -	9.23	0.213	3.32	0.327	20.0	5.41732	0.230855
1006-2	5	1-9-02	10-31-02	0.0496678	0.0090039	- -	- -	9.35	0.283	4.18	0.417	20.0	5.30933	0.168340
	14	11-1-02	6-30-03	0.0490642	0.0065297	- -	- -	9.46	0.203	4.04	0.407	20.0	5.41527	0.160503
	22	7-1-03	1-21-04	0.0461786	0.0079007	- -	- -	9.38	0.227	4.00	0.459	20.0	5.43687	0.171445
	30	1-22-04	5-13-13	0.0440739	0.0102981	- -	- -	9.35	0.223	3.94	0.448	20.0	5.46088	0.166630
1008	6	6-10-00	3-31-01	0.0872279	0.0087680	- -	- -	9.73	0.115	4.66	0.861	20.0	- -	- -
	24	4-1-01	9-4-01	0.0895442	0.0098604	- -	- -	9.75	0.102	4.57	0.803	20.0	- -	- -
	37	9-5-01	11-14-01	0.0899551	0.0096670	- -	- -	9.74	0.100	4.52	0.773	20.0	- -	- -
	38	11-15-01	5-13-13	0.0899551	0.0096670	- -	- -	9.74	0.100	4.52	0.773	20.0	4.21605	0.122356
1008-1[6]	--	5-16-02	4-20-03	0.0899551	0.0096670	- -	- -	9.74	0.100	4.52	0.773	20.0	4.21605	0.122356
	10	4-21-03	6-20-04	0.0911968	0.0063810	- -	- -	9.75	0.099	4.75	0.823	20.0	4.34110	0.139270
	20	6-21-04	5-13-13	0.0930792	0.0059248	- -	- -	9.77	0.103	4.57	0.699	20.0	4.33528	0.118673
433	5	6-10-00	11-14-01	0.1601833	0.0204379	- -	- -	9.41	0.257	4.96	0.697	20.0	- -	- -
	19	11-15-01	5-13-13	0.1601833	0.0204379	- -	- -	9.41	0.257	4.96	0.697	20.0	3.31554	0.111867
433-1	5	8-15-01	11-14-01	0.1700213	0.0433403	121.09	5.752	9.31	0.242	4.28	0.826	20.0	- -	- -
	6	11-15-01	2-28-02	0.1700213	0.0433403	121.09	5.752	9.31	0.242	4.28	0.826	20.0	3.41045	0.111867[5]
	11	3-1-02	2-23-03	0.1684402	0.0402156	121.09	5.752	9.27	0.281	4.27	0.557	20.0	3.55682	0.298299
	22	2-24-03	2-23-04	0.1643104	0.0321605	121.09	5.752	9.30	0.306	4.57	0.760	20.0	3.59344	0.227054
	31	2-24-04	6-12-10	0.1635099	0.0302263	121.09	5.752	9.30	0.300	4.59	0.697	20.0	3.55500	0.229905
	30	6-13-10	4-30-13	0.1635099	0.0302263	121.09	7.701	9.30	0.300	4.59	0.697	20.0	3.55500	0.229905
	30	5-1-13	***	0.1635099	0.0302263	121.09	7.701	9.30	0.300	4.59	0.697	N/A	3.55500	0.229905

1 Effective for all tests completed on or after this date.
2 *** = currently in effect.
3 Transformation is 1/Sqrt(VIS80).
4 Transformation is ln(VIS60).
5 Standard deviation based on oil 433.
6 Initial targets based on oil 1008.

7

Sequence IIIG Reference Oil Targets									
		Effective Dates		PVIS[3]		WPD		ACLW[4]	
Oil	n	From[1]	To[2]	$\bar{X}$	s	$\bar{X}$	s	$\bar{X}$	s
434	12	5-1-03	1-31-04	4.7623	0.4402	4.90	1.12	3.5306	0.1644
	20	2-1-04	5-31-04	4.7040	0.3877	4.73	1.01	3.4872	0.2061
	23	6-1-04	***	4.7269	0.3859	4.80	0.96	3.4657	0.1993
435	12	5-1-03	1-31-04	5.3726	0.2715	3.44	0.45	3.5851	0.2186
	19	2-1-04	5-31-04	5.2903	0.2852	3.53	0.47	3.5596	0.1960
	26	6-1-04	9-30-04	5.2333	0.2924	3.59	0.51	3.5044	0.2256
	31	10-1-04	***	5.1838	0.3096	3.59	0.58	3.4985	0.2342
435-2	-	2-1-11	***	5.1838	0.3096	3.59	0.58	3.4985	0.2342
438	13	5-1-03	1-31-04	4.5867	0.2106	3.20	0.42	2.8697	0.1649
	22	2-1-04	5-31-04	4.5707	0.1953	3.22	0.36	2.8902	0.1946
	25	6-1-04	8-31-04	4.5761	0.1877	3.20	0.35	2.8799	0.1864
	30	9-1-04	***	4.5706	0.1768	3.20	0.33	2.8814	0.2082

1 Effective for all tests completed on or after this date
2 *** = Currently in effect
3 Transformation is ln(PVIS)
4 Transformation is ln(ACLW)

Sequence IIIGA Reference Oil Targets					
		Effective Dates		MRV Viscosity[3]	
Oil	n	From[1]	To[2]	$\overline{X}$	s
434	16	11-3-03	1-31-04	10.7440	0.38793
	20	2-1-04	5-31-04	10.7378	0.40442
	23	6-1-04	***	10.7881	0.45550
435[4]	- -	11-3-03	***	- -	- -
435-2[4]	- -	2-1-11	***	- -	- -
438	16	11-3-03	1-31-04	9.8632	0.19411
	22	2-1-04	5-31-04	9.8351	0.17518
	25	6-1-04	8-31-04	9.8405	0.16998
	30	9-1-04	***	9.8277	0.16646

1 Effective for all tests completed on or after this date

2 *** = Currently in effect

3 Transformation is ln(MRV)

4 For oil 435, use Sequence IIIG PVIS Yi value as MRV Yi value

Sequence IIIGB Reference Oil Targets					
		Effective Dates		Phosphorus Retention	
Oil	n	From[1]	To[2]	$\overline{X}$	s
434	54	11-12-08	***	76.00	2.02
434-1[3]	--	11-12-08	***	76.00	2.02
435	51	11-12-08	***	82.40	2.28
435-2	--	2-1-11	***	82.40	2.28
438	53	11-12-08	***	78.20	2.56

1 Effective for all tests completed on or after this date
2 *** = Currently in effect
3 Targets based on oil 434

Sequence IVA Reference Oil Targets					
Oil	n	Effective Dates		Average Camshaft Wear	
		From[1]	To[2]	$\overline{X}$	s
1006	24[4]	8-19-98	9-30-99	115.80	9.47[3]
	5[5]	10-1-99	1-25-00	117.14[5]	12.23[5]
	10	1-26-00	5-23-01	121.38	9.86
	77	5-24-01	***	121.76	12.50
1006-2	6	2-11-02	7-18-02	88.74	12.50[6]
	11	7-19-02	1-20-04	90.72	11.16
	22	1-21-04	2-01-12	91.15	8.93
	4	2-2-12	7-10-12	100.18	18.65
	15	7-11-12	3-19-13	103.39	13.68
	29	3-20-13	***	102.18	13.54
1007	24[4]	8-19-98	9-30-99	95.58	9.47[3]
	11	5-24-01	12-31-02	92.12	16.76
	21	1-1-03	7-27-04	86.94	16.22
	31	7-28-04	***	84.76	15.40
1008	24[4]	8-19-98	9-30-99	40.16	9.47[3]
1009	5	12-18-02	4-30-04	21.03	6.23
	11	5-1-04	11-13-07	19.08	5.60
	29	11-14-07	6-1-11	18.76	7.05

1 Effective for all tests completed on or after this date
2 *** = currently in effect
3 Pooled s from GF-3 matrix analysis
4 GF-3 matrix n-size
5 Individual oil 1006 statistics from prove-out matrix
6 Standard deviation based on oil 1006

Sequence VG Reference Oil Targets														
Oil	n	Effective Dates		AES		RCS		AEV		APV		OSCRNSLG[7]		Hot Stuck Rings
		From[1]	To[2]	$\bar{X}$	S	$\bar{X}$	s	$\bar{X}$	s	$\bar{X}$	s	$\bar{X}$	s	Maximum Allowable
925-3	4	11-17-00	5-31-01	6.44	0.83	7.60	0.36	8.52	0.29	7.39	0.41	3.992	1.018	0
	10	6-1-01	11-02-04	6.23	0.62	7.38	0.45	8.57	0.24	7.40	0.28	4.147	0.649	0
	22	11-3-04	5-2-05	6.51	0.60	7.40	0.48	8.58	0.20	7.38	0.28	4.084	0.665	0
	26	5-3-05	7-28-11	6.49	0.55	7.43	0.44	8.56	0.20	7.38	0.26	3.997	0.669	0
	30	7-29-11	***	6.49	0.55	7.43	0.44	8.56	0.25[7]	7.38	0.36[7]	3.997	0.669	0
940[8]	5	11-14-12	9-24-13	6.43	0.51	8.15	0.44	8.79	0.25	7.20	0.63	3.951	0.840	0
	5	9-25-13	***	6.43	0.51	8.15	0.92	8.79	0.25	7.20	0.63	3.951	0.840	0
1006	18[4]	9-16-98	5-31-99	6.64	0.61[3]	8.23	0.56[3]	8.91	0.23[3]	7.72	0.32[3]	4.615	1.313[3]	0
	14[6]	6-1-99	11-15-99	8.11	0.68[5]	9.28	0.32[5]	9.25	0.10[5]	8.48	0.26[5]	1.680	0.645[5]	0
	10	11-16-99	5-24-00	8.35	0.72	9.34	0.26	9.27	0.12	8.56	0.20	1.412	0.828	0
	20	5-25-00	11-16-00	8.29	0.60	9.31	0.21	9.26	0.11	8.51	0.20	1.342	0.894	0
	29	11-17-00	***	8.43	0.60	9.35	0.20	9.27	0.10	8.49	0.18	1.384	0.850	0
1006-2	10	1-27-03	1-4-04	8.64	0.31	9.37	0.14	9.26	0.10	8.54	0.12	1.092	0.782	0
	20	1-5-04	11-02-04	8.69	0.42	9.41	0.16	9.25	0.11	8.54	0.13	0.918	0.649	0
	30	11-03-04	7-28-11	8.65	0.41	9.40	0.15	9.24	0.11	8.52	0.14	0.896	0.579	0
	30	7-29-11	9-24-13	8.65	0.41	9.40	0.15	9.24	0.12[7]	8.52	0.22[7]	0.896	0.579	0
	30	9-25-13	***	8.65	0.52	9.40	0.34	9.24	0.22	8.52	0.43	0.896	1.038	0
1007	18[4]	9-16-98	5-31-99	7.02	0.61[3]	7.72	0.56[3]	8.88	0.23[3]	7.83	0.32[3]	4.581	1.313[3]	0
	14[6]	6-1-99	11-15-99	9.16	0.68[5]	9.25	0.32[5]	9.28	0.10[5]	8.64	0.26[5]	0.462	0.645[5]	0
	10	11-16-99	11-16-00	8.94	0.28	9.06	0.30	9.24	0.09	8.59	0.13	0.801	0.667	0
	29	11-17-00	7-28-11	8.93	0.30	8.99	0.41	9.24	0.09	8.57	0.16	0.968	0.614	0
	30	7-29-11	***	8.93	0.30	8.99	0.41	9.24	0.11[7]	8.57	0.23[7]	0.968	0.614	0
1008	18[4]	9-16-98	8-13-99	9.00	0.61[3]	8.94	0.56[3]	9.16	0.23[3]	8.97	0.32[3]	0.660	1.313[3]	0

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Sequence VG Reference Oil Targets (continued)														
Oil	n	Effective Dates		AES		RCS		AEV		APV		OSCRNSLG[7]		Hot Stuck Rings
		From[1]	To[2]	$\overline{X}$	S	$\overline{X}$	s	$\overline{X}$	s	$\overline{X}$	s	$\overline{X}$	s	Maximum Allowable
1009	3	8-1-02	10-4-02	8.00	0.22	9.25	0.09	8.93	0.16	7.80	0.54	1.823	0.739	0
	5	10-5-02	5-14-03	7.78	0.36	9.15	0.22	8.93	0.11	7.84	0.40	2.670	1.303	0
	10	5-15-03	2-16-04	7.82	0.46	9.23	0.19	9.01	0.16	7.85	0.33	2.362	1.337	0
	20	2-17-04	11-02-04	7.87	0.43	9.29	0.19	9.00	0.15	7.80	0.29	2.274	1.044	0
	30	11-03-04	7-28-11	7.94	0.52	9.29	0.18	8.99	0.11	7.79	0.28	2.200	1.038	0
	30	7-29-11	9-24-13	7.94	0.52	9.29	0.18	8.99	0.22[7]	7.79	0.43[7]	2.200	1.038	0
	30	9-25-13	***	7.94	0.52	9.29	0.27	8.99	0.22[7]	7.79	0.43[7]	2.200	1.038	0

1 Effective for all tests completed on or after this date.
2 *** = currently in effect.
3 Pooled s from GF-3 matrix analysis.
4 GF-3matrix n-size
5 Pooled s from fuel matrix analysis
6 Fuel matrix n-size
7 Updated AEV and APV standard deviations using last 30 tests, including fuel. approval results for oil 925-3, 1006-2, 1007 and 1009
8 See TMC Memo 12-033

Sequence VIB Reference Oil Targets							
Oil	n	Effective Dates		FEI1		FEI2	
		From[1]	To[2]	$\bar{X}$	s	$\bar{X}$	s
538	7	1-17-02	7-11-02	2.07	0.22	1.60	0.21
	21	7-12-02	10-15-02	1.90	0.22	1.57	0.21
	30	10-16-02	***	1.89	0.22	1.55	0.21
538-1	7	11-15-07	2-4-08	1.98	0.22	1.58	0.21
	10	2-5-08	2-10-09	2.02	0.22	1.53	0.21
	20	2-11-09	***	2.02	0.22	1.47	0.21
539	7	12-3-07	1-29-08	0.91	0.22	0.33	0.21
	10	1-30-08	3-25-09	0.91	0.22	0.38	0.21
	20	3-26-09	***	0.91	0.22	0.43	0.21
1006	12[4]	8-25-98	8-8-99	1.37	0.18[3]	0.38	0.17[3]
	19	8-9-99	***	1.40	0.22	0.50	0.21
1007	12[4]	8-25-98	8-8-99	0.70	0.18[3]	0.26	0.17[3]
	20	8-9-99	***	0.69	0.22	0.31	0.21
1008	12[4]	8-25-98	8-8-99	1.66	0.18[3]	1.13	0.17[3]
	24	8-9-99	***	1.88	0.22	1.27	0.21
1008-1[5]	--	6-1-02	11-14-02	1.88	0.22	1.27	0.21
	10	11-15-02	5-20-03	1.95	0.22	1.30	0.21
	20	5-21-03	7-2-03	1.90	0.22	1.27	0.21
	30	7-3-03	***	1.96	0.22	1.30	0.21

1 Effective for all tests completed on or after this date.
2 *** = currently in effect.
3 Pooled s from matrix analysis.
4 Matrix n-size.
5 Initial targets based on oil 1008.

Sequence VID Reference Oil Targets							
Oil	n	Effective Dates		FEI1		FEI2	
		From[1]	To[2]	$\overline{X}$	s[3]	$\overline{X}$	s[3]
540 (GF5A)	11[4]	12-29-08	12-2-09	1.32	0.14	1.04	0.16
540 (GF5A)	11[4]	12-3-09	***	1.32	0.12[5]	1.04	0.14[5]
GF5B	3[4]	12-29-08	***	0.97	0.14	0.63	0.16
GF5C	4[4]	12-29-08	***	1.24	0.14	0.59	0.16
541 (GF5D)	11[4]	12-29-08	12-2-09	0.87	0.14	0.71	0.16
541 (GF5D)	11[4]	12-3-09	***	0.87	0.12[5]	0.71	0.14[5]
542 (GF5X)	11[4]	12-29-08	12-2-09	1.49	0.14	0.80	0.16
542 (GF5X)	11[4]	12-3-09	***	1.49	0.12[5]	0.80	0.14[5]
1010	5	12-01-10	9-27-11	1.31	0.12[5]	1.23	0.14[5]
1010	28	9-28-11	***	1.34	0.12[5]	1.10	0.18[6]

1 Effective for all tests completed on or after this date.
2 *** = currently in effect.
3 Pooled s from matrix analysis.
4 Matrix n-size.
5 November 2009 Pooled s calculation based on additional data– reference oil n-size used= 540-36, 541-24, 542-33, GF5B-3 and GF5C-4.
6 Standard deviation based on 28 operationally valid results.

Sequence VIII Reference Oil Targets							
		Effective Dates		TBWL		10 Hr. Stripped Viscosity	
Oil	n	From[1]	To[2]	$\bar{X}$	s	$\bar{X}$	s
704-1	10[4]	8-29-98	11-16-99	7.9	3.40[3]	10.27	0.12[3]
	11	11-17-99	4-15-01	8.0	3.40	10.25	0.15
	23	4-16-01	12-16-01	8.3	2.44	10.29	0.11
	35	12-17-01	***	8.3	2.32	10.27	0.11
1006	10[4]	8-29-98	11-16-99	19.6	3.40[3]	9.09	0.12[3]
	10	11-17-99	4-15-01	17.1	5.28	9.00	0.22
	23	4-16-01	12-16-01	15.6	4.66	8.98	0.19
	32	12-17-01	***	15.9	4.85	9.00	0.17
1006-2	7	10-25-02	8-31-03	13.0	4.26	9.23	0.07
	12	9-1-03	5-14-04	12.4	2.59	9.24	0.06
	20	5-15-04	9-18-06	12.6	2.81	9.24	0.07
	--	9-19-06	3-11-07	15.9[5]	4.85[5]	9.24	0.07
	11	3-12-07	***	17.5	4.23	9.37	0.07
1009	5	1-7-03	1-23-05	12.8	2.00	9.51	0.10
	11	1-24-05	***	13.8	2.14	9.51	0.10

1 Effective for all tests completed on or after this date.
2 *** = currently in effect.
3 Pooled s from GF-3 matrix analysis.
4 GF-3 matrix n-size.
5 Targets based on oil 1006.

1M-PC Reference Oil Targets							
		Effective Dates		WTD		TGF	
Oil	n	From[1]	To[2]	$\overline{X}$	s	$\overline{X}$	s
873	30	9-14-93	***	251.8	43.3	42.3	15.8
873-1	30	4-19-94	***	232.5	50.5	41.0	16.1
873-2[3]	--	4-28-02	***	232.5	50.5	41.0	16.1

1 Effective for all tests completed on or after this date.
2 *** = currently in effect.
3 Targets based on oil 873-1.

1K Reference Oil Targets											
		Effective Dates		WDK		TGF		TLHC[3]		BSOC	
Oil	n	From[1]	To[2]	$\overline{X}$	s	$\overline{X}$	s	$\overline{X}$	s	$\overline{X}$	s
809	30	5-6-90	***	219.2	41.9	12.3	6.3	0.398	0.9	0.272	0.117
809-1	30	8-16-91	***	216.4	35.6	17.5	15.7	0.605	1.1	0.268	0.145
810-2[5]	--	2-1-98	12-31-99	247.4	38.4	53.8	22.1	2.065	1.4	0.309	0.212
	8	1-1-00	***	261.3	38.8	55.3	20.2	1.935	1.7	0.375	0.331
811[4]	--	7-1-90	8-20-91	327.7	55.9	27.3	16.6	0.868	1.0	0.267	0.097
811-1	30	1-1-91	***	327.7	55.9	27.3	16.6	0.868	1.0	0.267	0.097

1 Effective for all tests completed on or after this date.
2 *** = currently in effect.
3 Transformation for TLHC is ln(TLHC+1)
4 Targets based on 811-1.
5 Targets based on 810-1.

1N Reference Oil Targets											
		Effective Dates		WDN		TGF		TLHC[3]		BSOC	
Oil	n	From[1]	To[2]	$\bar{X}$	s	$\bar{X}$	s	$\bar{X}$	s	$\bar{X}$	s
809-1	18	3-14-93	12-7-95	196.6	33.3	32.1	18.8	1.386	1.1	0.325	0.215
	20	12-8-95	12-6-07	198.1	33.1	33.9	20.5	1.363	1.1	0.322	0.204
	30	12-7-07	***	205.0	34.6	35.3	20.5	1.197	1.213	0.308	0.175
810-2	8[5]	2-1-98	12-31-99	270.5	39.3	73.6	11.8	2.632	1.2	0.500	0.407
	4	1-1-00	***	273.3	45.5	70.8	11.0	2.548	1.3	0.540	0.410
811-1	10	3-22-93	3-28-96	293.8	38.6	28.9	26.5	0.262	0.5	0.249	0.051
	20	3-29-96	12-6-07	281.5	37.4	24.7	21.6	0.366	0.6	0.223	0.052
	30	12-7-07	***	273.2	35.5	26.2	19.8	0.454	0.659	0.218	0.053
811-2[7]	--	11-26-06	***	281.5	37.4	24.7	21.6	0.366	0.6	0.223	0.052
1004	16	6-29-93	***	224.7	37.5	24.8	13.8	0.588	0.8	0.192	0.048
1004-1	30	2-6-94	***	212.4	27.1	24.7	14.6	0.693	0.9	0.201	0.045
1004-2[4]	--	8-11-95	12-10-96	212.3	27.1	24.7	14.6	0.693	0.9	0.201	0.045
	12	12-11-96	12-21-97	205.9	28.9	31.7	14.8	0.552	0.904	0.206	0.093
	22	12-22-97	***	204.0	25.7	30.4	16.8	0.490	0.804	0.206	0.075
1004-3[6]	--	4-17-99	3-13-04	204.0	25.7	30.4	16.8	0.490	0.804	0.206	0.075
	16	3-14-04	***	190.7	24.7	23.9	14.6	0.1806	0.3977	0.148	0.038

1 Effective for all tests completed on or after this date.
2 *** = currently in effect.
3 Transformation for TLHC is ln(TLHC+1).
4 Initial targets based on 1004-1.
5 Three runs on 810-1 and five runs on 810-2.
6 Initial targets based on 1004-2.
7 Initial targets based on 811-1

1P Reference Oil Targets													
Oil	n	Effective Dates		TGC		TLC		AOC[1]		WDP		EOTOC[2]	
		From	To[3]	$\overline{X}$	s	$\overline{X}$	s	$\overline{X}$	s	$\overline{X}$	s	$\overline{X}$	s
1005	31	2-19-97	***	28.65	7.74	30.88	13.15	1.8641	0.3238	285.3	57.6	1.6016	0.5177
1005-1[5]	--	6-6-98	***	28.65	7.74	30.88	13.15	1.8641	0.3238	285.3	57.6	1.6016	0.5177
1005-2[5]	--	7-15-05	***	28.65	7.74	30.88	13.15	1.8641	0.3238	285.3	57.6	1.6016	0.5177
1005-3[5]	--	12-30-09	***	28.65	7.74	30.88	13.15	1.8641	0.3238	285.3	57.6	1.6016	0.5177
1005-4[5]	--	06-01-13	***	28.65	7.74	30.88	13.15	1.8641	0.3238	285.3	57.6	1.6016	0.5177
1004-3	31	2-19-97	***	29.48	7.74	28.12	13.15	1.8321	0.3238	319.6	57.6	2.0492	0.5177
PC-7C[4]	31	2-19-97	***	42.63	7.74	42.03	13.15	2.8999	0.3238	390.2	57.6	3.4664	0.5177
PC-7D[4]	31	2-19-97	***	31.71	7.74	40.29	13.15	1.9572	0.3238	307.6	57.6	2.0719	0.5177
PC-7E[4]	31	2-19-97	***	32.53	7.74	37.52	13.15	1.9252	0.3238	341.9	57.6	2.5195	0.5177
PC-7F[4]	31	2-19-97	***	45.68	7.74	51.44	13.15	2.9930	0.3238	412.5	57.6	3.9367	0.5177
PC-7G[4]	31	2-19-97	***	25.49	7.74	29.87	13.15	1.8680	0.3238	279.7	57.6	1.5609	0.5177
PC-7H[4]	31	2-19-97	***	26.32	7.74	27.11	13.15	1.8360	0.3238	314.0	57.6	2.0084	0.5177
PC-7J[4]	31	2-19-97	***	39.46	7.74	41.02	13.15	2.9039	0.3238	384.6	57.6	3.4257	0.5177

1 Transformation for AOC is ln(AOC)
2 Transformation for EOTOC is ln(EOTOC)
3 *** = currently in effect
4 Oil used only for precision matrix
5 Targets based on 1005

1R Reference Oil Targets													
		Effective Dates		WDR		TGC		TLC		IOC		EOTOC	
Oil	n	From	To[1]	$\overline{X}$	s	$\overline{X}$	s	$\overline{X}$	s	$\overline{X}$	s	$\overline{X}$	s
820 (PC-9A)	7	7-1-01	12-31-01	341.2	36.2	34.11	10.28	22.82	10.50	8.3	1.7	7.9	2.6
820-2[2]	--	1-1-02	***	341.2	36.2	34.11	10.28	22.82	10.50	8.3	1.7	7.9	2.6
PC-9D[3]	2	7-1-01	***	285.9	6.5	28.13	3.01	13.75	8.84	10.0	2.3	10.2	1.3
1005-1	15	7-1-01	12-9-01	327.3	23.7	34.50	8.72	18.60	5.66	9.9	1.2	8.3	1.0
	20	12-10-01	***	327.9	23.1	34.51	8.70	18.61	6.00	10.0	1.1	8.3	1.0
1005-2	--	09-01-10	***	327.9	23.1	34.51	8.70	18.61	6.00	10.0	1.1	8.3	1.0
1005-3	--	09-01-10	***	327.9	23.1	34.51	8.70	18.61	6.00	10.0	1.1	8.3	1.0
1005-4	--	04-01-13	***	327.9	23.1	34.51	8.70	18.61	6.00	10.0	1.1	8.3	1.0

1 *** = currently in effect
2 Targets based on oil 820
3 Oil used only for precision matrix

C13 Reference Oil Targets											
		Effective Dates		Top Groove Carbon		Top Land Carbon		Oil Consumption Δ^2		2nd Ring Top Carbon[3]	
Oil	n	From	To[1]	$\overline{X}$	s	$\overline{X}$	s	$\overline{X}$	s	$\overline{X}$	s
PC10A	3	5-28-05	2-20-06	45.55	6.44	23.18	5.57	6.2676	0.8226	2.3301	0.3430
PC10C	2	5-28-05	2-20-06	54.57	2.92	26.98	0.21	5.7229	1.8966	3.2447	0.3966
PC10D	3	5-28-05	2-20-06	39.18	5.85	23.58	2.33	3.8405	1.8509	2.4426	0.3400
PC10E	7	5-28-05	2-20-06	45.52	8.02	23.52	7.02	4.8593	1.4265	2.8197	0.4024
PC10F	3	5-28-05	2-20-06	54.08	11.09	36.32	2.82	6.5929	0.9750	3.8424	0.2573
PC10G	3	5-28-05	2-20-06	35.85	2.83	29.05	0.84	3.8066	0.8456	2.7134	0.1936
831 (PC10B)	8	5-28-05	3-12-08	45.18	7.42	24.99	7.59	5.7336	0.7280	2.8945	0.2055
	14	3-13-08	***	46.02	5.90	21.87	7.89	5.5089	0.7141	2.8828	0.2900
831-1[4]	--	05-10-08	***	46.02	5.90	21.87	7.89	5.5089	0.7141	2.8828	0.2900
831-2[4]	--	08-06-13	***	46.02	5.90	21.87	7.89	5.5089	0.7141	2.8828	0.2900

1 *** = Currently in effect
2 Transformation for Oil Consumption Delta is sqrt(OC Δ)
3 Transformation for 2nd Ring Top Carbon is ln(R2TC)
4 Targets based on oil 831

ISB Reference Oil Targets							
Oil	n	Effective Dates		Average Camshaft Wear		Average Tappet Weight Loss	
		From	To[1]	$\overline{X}$	s	$\overline{X}$	s
821 (PC10E)	6	6-4-05	12-31-05	34.6	4.6	56.2	9.6
830-2	6	6-4-05	12-31-05	39.8	9.0	85.9	16.0
831 (PC10B)	6	6-4-05	1-24-07	41.9	5.6	88.7	15.9
	10	1-25-07	8-6-07	42.8	5.4	94.9	15.3
	14	8-7-07	***	42.5	5.0	97.2	14.8
831-1[2]	--	8-7-07	***	42.5	5.0	97.2	14.8
831-2[2]	--	8-6-13	***	42.5	5.0	97.2	14.8

1 *** = currently in effect
2 Targets based on oil 831

ISM Reference Oil Targets											
Oil	n	Effective Dates		X-Head Wear @ 3.9% Soot		OFDP[1]		Average Sludge		Injector Adj. Screw Wear @ 3.9% Soot	
		From	To[2]	$\overline{X}$	s	$\overline{X}$	s	$\overline{X}$	s	$\overline{X}$	s
830-2	7	9-1-04	11-30-05	4.8	1.4	2.5430	0.3936	9.04	0.20	30.0	7.0
	10	12-1-05	8-6-07	5.3	1.4	2.4342	0.3813	8.99	0.15	24.5	10.7
	21	8-7-07	***	5.1	1.5	2.5209	0.3274	9.00	0.15	29.5	5.7

1 Transformation for OFDP is ln(OFDP+1)
2 *** = currently in effect

T-8 Reference Oil Targets					
		Effective Dates		Viscosity Increase @ 3.8% Soot	
Oil	n	From[1]	To[2]	$\bar{X}$	s
1004-1	30	4-1-94	***	5.13	1.19
1004-2	10	7-1-95	10-31-95	4.49	1.19[3]
	20	11-1-95	1-31-96	4.46	1.19[3]
	30	2-1-96	9-30-96	4.46	1.19[3]
	59	10-1-96	***	4.92	0.93
1004-3	--	11-15-97	4-30-98	4.92[4]	0.93[4]
	10	5-1-98	9-13-98	4.71	0.97
	22	9-14-98	1-31-99	4.57	0.95
	30	2-1-99	***	4.57	0.90
1005-2	5	5-24-07	1-24-08	5.85[5]	0.72[5]
	3	1-25-08	2-6-08	4.83	0.72[5]
	5	2-7-08	***	5.11	0.66
1005-3[6]	--	08-12-10	9-16-11	5.11	0.66
	--	9-17-11	***	5.01[7]	0.56[7]
1005-4[7]	--	09-21-12	***	5.01[7]	0.56[7]

1 Effective for all tests completed on or after this date.
2 *** = currently in effect.
3 Standard deviation based on 1004-1.
4 Targets based on 1004-2.
5 Targets based on previous tests on 1005.
6 Targets based on 1005-2.
7 Targets based on all blends of 1005.

T-8E Reference Oil Targets							
		Effective Dates		Relative Viscosity @ 4.8% Soot 50% DIN Shear Loss		Relative Viscosity @ 4.8% Soot 100% DIN Shear Loss	
Oil	n	From[1]	To[2]	$\overline{X}$	s	$\overline{X}$	s
1004-2	24	1-27-97	***	2.02	0.26	--	--
1004-3	--	11-15-97	4-30-98	2.02[3]	0.26[3]	--	--
	10	5-1-98	9-13-98	2.10	0.29	--	--
	21	9-14-98	1-31-99	2.09	0.27	--	--
	30	2-1-99	***	2.07	0.26	--	--
	59	2-1-98	***	--	--	2.21	0.27
1005-2	5	5-24-07	1-24-08	2.09[4]	0.15[4]	2.42[4]	0.16[4]
	3	1-25-08	2-6-08	1.74	0.15[4]	1.98	0.16[4]
	5	2-7-08	***	1.78	0.11	2.03	0.12
1005-3[5]	--	08-12-10	9-16-11	1.78	0.11	2.03	0.12
	--	9-17-11	***	1.76[6]	0.08[6]	2.00[6]	0.09[6]
1005-4[6]	--	09-21-12	***	1.76[6]	0.08[6]	2.00[6]	0.09[6]

1 Effective for all tests completed on or after this date.
2 *** = currently in effect.
3 Targets based on 1004-2.
4 Targets based on previous tests on 1005.
5 Targets based on 1005-2
6 Targets based on all blends of 1005.

T-10A Reference Oil Targets[1]					
		Effective Dates		MRV Viscosity	
Oil	n	From	To[2]	$\bar{X}$	s
820 (PC-9A)	13	12-11-00	1-4-02	14384	511
820-1[3]	--	11-5-01	11-9-01	14384	511
820-2	14	1-16-02	9-24-02	13060	643
	26	9-25-02	1-21-03	13109	496
	30[4]	1-22-03	***	13128	497
820-3[5]	--	04-23-09	***	13128	497

1 Control charts use only most recent targets for each oil
2 *** = currently in effect
3 Targets based on oil 820
4 Targets used for control charts effective 1-16-02 and severity adjustments effective 1-22-03
5 Targets based on oil 820-2

T-11 Reference Oil Targets											
		Effective Dates		Soot @ 4.0 cSt Vis. Inc		Soot @ 12.0 cSt Vis. Inc		Soot @ 15.0 cSt Vis. Inc.		MRV Viscosity	
Oil	n	From	To[1]	$\overline{X}$	S	$\overline{X}$	s	$\overline{X}$	s	$\overline{X}$	s
820-2	32	3-8-03	***	--	--	5.78	0.21	--	--	14969	1097
820-2	16	5-28-05	5-31-10	3.81	0.23	5.78[2]	0.21[2]	6.36	0.26	14969[2]	1097[2]
	--[3]	6-1-10	***	3.95	0.30	5.92	0.22	6.51	0.20	14981	916
820-3	11	9-7-07	***	3.95	0.30	5.92	0.22	6.51	0.20	14981	916
822-1	4	2-1-2013	7-2-2013	3.99	0.21	5.65	0.54	6.35	0.66	14408	314
	8	7-3-2013	***	4.09	0.20	5.81	0.50	6.48	0.61	13948	584
822-2	8	1-1-2014	***	4.09	0.20	5.81	0.50	6.48	0.61	13948	584

1 *** = currently in effect
2 Value based on earlier data set (n=32)
3 Targets based on oil 820-3

T-12 Reference Oil Targets														
			Effective Dates		Cylinder Liner Wear		Top Ring Weight Loss		Oil Consumption		ΔPB @ End of Test		ΔPB 250-300 Hours	
Oil	Level	n	From	To[1]	$\bar{X}$	s	$\bar{X}$	s	$\bar{X}$	s	$\bar{X}$	s	$\bar{X}$	s
820-2	Stand	4	2-19-05	3-20-05	23.2	4.5	102.0	15.0	4.2770	0.0950	3.0269	0.2034	2.1647	0.1074
820-2	Lab	4	2-19-05	3-20-05	23.2	4.5	102.0	15.0	4.2770	0.0950	3.0269	0.2034	2.1647	0.1074
820-2	Stand	8	6-13-05	12-31-05	18.2	3.5	54.6	24.9	4.2040	0.0610	2.9250	0.2880	2.0020	0.3630
820-2	Lab	8	6-13-05	12-31-05	19.2	1.6	54.6	24.9	4.2040	0.0610	2.9250	0.2880	2.0020	0.3630
831 (PC10B)	Stand	5	6-13-05	12-31-05	12.8	3.2	54.5	24.9	4.1240	0.0610	3.3770	0.2880	2.2450	0.3630
831 (PC10B)	Lab	5	6-13-05	12-31-05	12.5	1.6	54.5	24.9	4.1240	0.0610	3.3770	0.2880	2.2450	0.3630
821 (PC10E)	Stand	6	6-13-05	3-12-08	15.1	3.4	66.4	24.9	4.0830	0.0610	3.2590	0.2880	2.2510	0.3630
821 (PC10E)	Stand	25	3-13-08	***	16.2	3.7	62.0	28.2	4.0930	0.0790	3.1060	0.2420	2.1250	0.3330
821 (PC10E)	Lab	6	6-13-05	3-12-08	14.6	1.6	66.4	24.9	4.0830	0.0610	3.2590	0.2880	2.2510	0.3630
821 (PC10E)	Lab	25	3-13-08	***	15.1	2.8	62.0	28.2	4.0930	0.0790	3.1060	0.2420	2.1250	0.3330
821-1[2]	Stand	--	3-13-08	***	16.2	3.7	62.0	28.2	4.0930	0.0790	3.1060	0.2420	2.1250	0.3330
821-1[2]	Lab	--	3-13-08	***	15.1	2.8	62.0	28.2	4.0930	0.0790	3.1060	0.2420	2.1250	0.3330
821-2[3]	Stand	--	9-27-11	***	16.2	3.7	62.0	28.2	4.0930	0.0790	3.1060	0.2420	2.1250	0.3330
821-2[3]	Lab	--	9-27-11	***	15.1	2.8	62.0	28.2	4.0930	0.0790	3.1060	0.2420	2.1250	0.3330
821-3[3]	Stand	--	8-21-12	***	16.2	3.7	62.0	28.2	4.0930	0.0790	3.1060	0.2420	2.1250	0.3330
821-3[3]	Lab	--	8-21-12	***	15.1	2.8	62.0	28.2	4.0930	0.0790	3.1060	0.2420	2.1250	0.3330
821-4[3]	Stand	--	4-29-14	***	16.2	3.7	62.0	28.2	4.0930	0.0790	3.1060	0.2420	2.1250	0.3330
821-4[3]	Lab	--	4-29-14	***	15.1	2.8	62.0	28.2	4.0930	0.0790	3.1060	0.2420	2.1250	0.3330

1 *** = currently in effect
2 Targets based on oil 821
3 Targets based on 25 tests on 821

Roller Follower Wear Test Reference Oil Targets						
Engine Type	Oil	n	Effective Dates		Average Wear	
			From[1]	To[2]	$\overline{X}$	s
6.2L	1004	15	5-27-93	5-31-96	0.40	0.08
	1004-1	--	2-1-94	10-16-94	0.40	0.08
		10	10-17-94	6-25-95	0.36	0.05
		21	6-26-95	5-31-96	0.35	0.04
	1004-2[3]	--	9-1-95	5-31-96	0.35	0.04
6.5L	1004-1	--	6-1-96	***	0.35	0.06[5]
	1004-2	--	6-1-96	12-31-97	0.35[4]	0.06[5]
		10	1-1-98	***	0.33	0.05
	1004-3	2	1-1-98	***	0.44	0.06
	1005	2	6-1-96	5-24-97	0.20	0.06
		4	5-25-97	8-11-97	0.19	0.06
		6	8-12-97	***	0.20	0.06
	1005-1[6]	--	5-1-98	10-31-00	0.20	0.06
		5	11-1-00	***	0.20	0.05[7]
	1005-2[8]	--	11-1-00	***	0.20	0.05
	1005-3[8]	--	08-20-10	***	0.20	0.05
	1005-4[8]	--	10-00-13	***	0.20	0.05

1 Effective for all tests completed on or after this date.
2 *** = currently in effect.
3 Targets based on 1004-1.
4 Mean based on 1004-1.
5 Standard deviation based on all 6.2L results on all blends of 1004 through 5-31-96 (n=45).
6 Targets based on 1005.
7 Pooled standard deviation for all Roller Follower Wear reference oil tests through 10-12-00.
8 Targets based on 1005-1.

Engine Oil Aeration Test Reference Oil Targets					
		Effective Dates		Average Engine Oil Aeration	
Oil	n	From[1]	To[2]	$\overline{X}$	s
1004-2	13	6-2-95	***	9.46	0.25
1004-3	--	10-25-97	***	9.46[3]	0.25[4]
1005	2	5-10-97	***	7.80	0.25[4]
1005-1	--	8-12-98	***	7.80[5]	0.25[4]
1005-2[6]	--	09-30-05	***	7.80[5]	0.25[4]
1005-3[6]	--	01-01-11	***	7.80[5]	0.25[4]
1005-4[6]	--	01-01-13	***	7.80[5]	0.25[4]

1 Effective for all tests completed on or after this date.
2 *** = currently in effect.
3 Mean based on 1004-2.
4 Standard deviation based on 1004-2.
5 Mean based on 1005.
6 Targets based on 1005-1

T-12A Reference Oil Targets					
		Effective Dates		MRV Viscosity	
Oil	n	From[1]	To[2]	$\overline{X}$	s
821-1	14[3]	2-16-10	***	11736	331
821-2	14[3]	2-16-10	***	11736	331
821-3	14[3]	8-21-12	***	11736	331
821-4	14[3]	4-29-14	***	11736	331

1 Effective for all tests completed on or after this date.
2 *** = currently in effect.
3 n-size is based on 14 T-12 tests using 821 and 821-1 run for T-12A development

L-33-1 Reference Oil Targets						
			Effective Dates		Rust	
Oil	Gear Version	n	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
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	2-8-06	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]

1 Effective for all tests completed on or after this date.
2 Based on V94.1 & V95.1 data.
3 Based on oil 121 data.
4 Based on lab pooled s of V94.1 & V95.1 data (all blends of oil 121).
5 Based on oil 121-1 data.
6 Based on V99.1 data on oil 121-1.
7 Based on V99.1 and V95.1 data.
8 Based on lab pooled s of V94.1 & V95.1 data (all blends of oil 123).
9 Based on oil 123 data.
10 Based on V99.1 data on oil 123.
11 Based on V99.1 data on oil 151-3.
12 Based on V99.1 & V01.1 data on oil 151-3.

L-37 Reference Oil Targets																	
						Ridging			Rippling			Spitting			Wear		
Hardware	Pinion Batch	Oil	n	From	To	x	s	Bands	x	s	Bands	x	s	Bands	x	s	Bands
LUBRITED	C1L308	128	15	19000101	***	6.53	1.407	4 - 9	7.63	1.420	5 - 10	8.83	1.754	6 - 10	5.60	1.298	3 - 8
		128-1	7	19000101	***	7.00	0.000	7 - 7	8.00	0.577	7 - 9	8.84	1.723	6 - 10	5.57	0.535	5 - 7
		129	5	19000101	***	9.00	0.000	9 - 9	8.40	0.894	7 - 10	9.56	0.089	9.4 - 9.7	6.80	1.483	4 - 9
	C1L426	128	7	19000101	***	7.57	0.976	6 - 9	8.29	1.380	6 - 10	6.83	2.357	3 - 10	5.71	0.488	5 - 7
		128-1	7	19000101	***	7.71	1.113	6 - 10	7.86	0.690	7 - 9	7.57	3.187	2 - 10	6.00	0.577	5 - 7
		129	2	19000101	***	9.00	0.000	9 - 9	9.50	0.707	8 - 10	9.60	0.141	9.3 - 9.9	7.50	0.707	6 - 9
	L247	128-1	10	19000101	***	7.40	0.516	6 - 8	7.60	1.075	6 - 10	9.02	0.892	7 - 10	5.80	0.422	5 - 7
		151-3	10	19000101	***	8.80	0.422	8 - 10	8.60	0.516	8 - 10	9.49	0.586	8 - 10	6.00	0.000	6 - 6
		155	1	19000101	***	9.00	0.000	9 - 9	8.00	0.000	8 - 8	9.30	0.000	9.3 - 9.3	6.00	0.000	6 - 6
	V1L303	128	1	19000101	***	7.00	0.000	7 - 7	7.00	0.000	7 - 7	8.00	0.000	8 - 8	6.00	0.000	6 - 6
		128-1	30	19000101	***	7.30	1.264	5 - 10	6.97	1.497	4 - 10	5.26	3.144	0 - 10	5.67	0.959	4 - 7
		129	9	19000101	***	8.11	0.601	7 - 9	8.56	0.527	8 - 10	9.61	0.366	9 - 10	6.56	0.527	6 - 8
	V1L686	128-1	20	19000101	***	6.35	0.813	5 - 8	7.20	1.473	5 - 10	9.77	0.421	9 - 10	6.40	0.598	5 - 7
		151-3	21	19000101	***	6.43	1.207	4 - 9	8.71	0.463	8 - 10	9.68	0.632	9 - 10	6.57	0.598	5 - 8
		152	4	19000101	***	5.25	0.500	4 - 6	8.25	0.500	7 - 9	9.53	0.359	9 - 10	6.25	0.500	5 - 7
		153	2	19000101	***	5.00	0.000	5 - 5	8.00	0.000	8 - 8	9.30	0.424	9 - 10	5.50	0.707	4 - 7
		155	1	19000101	***	7.00	0.000	7 - 7	9.00	0.000	9 - 9	9.90	0.000	9.9 - 9.9	7.00	0.000	7 - 7
	V1L528	134	4	19000101	***	7.00	1.155	4 - 10	7.00	1.414	4 - 10	8.83	0.974	7 - 10	6.00	0.242	5 - 7
		152-1	6	19000101	***	8.00	0.632	7 - 10	8.83	0.753	7 - 10	9.88	0.041	9.3 - 10	7.00	0.242	6 - 8
		152-2	6	19000101	***	8.00	0.632	7 - 10	8.83	0.753	7 - 10	9.88	0.041	9.3 - 10	7.00	0.242	6 - 8
		155	8	19000101	***	8.29	0.488	7 - 10	8.86	0.690	7 - 10	9.90	0.436	9 - 10	6.86	0.378	6 - 8

L-37 Reference Oil Targets																	
						Ridging			Rippling			Spitting			Wear		
Hardware	Pinion Batch	Oil	n	From	To	x	s	Bands	x	s	Bands	x	s	Bands	x	s	Bands
NONLUBRITED	C1L308	127	17	19000101	***	6.41	2.033	3 - 10	6.06	1.784	3 - 9	9.54	0.450	9 - 10	6.82	2.038	3 - 10
		128	30	19000101	***	7.93	0.980	6 - 10	5.90	2.426	2 - 10	9.71	0.306	9.2 - 10	6.37	0.718	5 - 8
		128-1	8	19000101	***	8.38	0.744	7 - 10	5.75	1.982	2 - 9	9.43	0.883	8 - 10	6.50	0.535	6 - 7
		128-2	1	19000101	***	8.00	0.000	8 - 8	6.00	0.000	6 - 6	8.00	0.000	8 - 8	6.00	0.000	6 - 6
		129	19	19000101	***	9.26	0.933	8 - 10	9.89	0.315	9 - 10	9.89	0.091	9.7 - 10	8.11	0.875	7 - 10
	C1L426	127	10	19000101	***	7.25	1.752	4 - 10	8.30	1.767	5 - 10	9.40	1.039	8 - 10	6.50	0.972	5 - 8
		128	10	19000101	***	7.90	0.738	7 - 9	8.20	0.789	7 - 10	9.21	0.998	7 - 10	5.80	0.422	5 - 7
		128-1	11	19000101	***	8.36	0.674	7 - 10	8.00	1.095	6 - 10	9.54	0.785	8 - 10	5.73	0.467	5 - 7
		128-2	2	19000101	***	8.00	0.000	8 - 8	7.50	0.707	6 - 9	9.90	0.000	9.9 - 9.9	6.00	0.000	6 - 6
		129	8	19000101	***	9.50	0.535	9 - 10	9.75	0.463	9 - 10	9.96	0.052	9.9 - 10	7.00	1.195	5 - 9
	V1L176	127	2	19000101	***	7.00	2.828	2 - 10	8.00	0.000	8 - 8	6.45	4.879	0 - 10	6.00	1.414	3 - 9
		128-1	12	19000101	***	8.25	0.754	7 - 10	7.17	2.038	4 - 10	9.72	0.208	9.3 - 10	6.08	0.289	6 - 7
		128-2	1	19000101	***	7.00	0.000	7 - 7	9.00	0.000	9 - 9	9.90	0.000	9.9 - 9.9	6.00	0.000	6 - 6
		151-3	14	19000101	***	9.14	0.363	8 - 10	8.86	0.363	8 - 10	9.56	1.314	7 - 10	6.64	0.633	6 - 8
	V1L303	127	3	19000101	***	6.67	1.155	5 - 9	6.67	2.082	3 - 10	9.80	0.173	9.5 - 10	6.00	0.000	6 - 6
		128-1	13	19000101	***	8.08	0.494	7 - 9	6.92	1.656	4 - 10	8.07	2.451	4 - 10	5.85	0.376	5 - 7
		129	4	19000101	***	9.50	0.577	8 - 10	9.00	0.816	8 - 10	9.93	0.050	9.8 - 10	6.75	0.957	5 - 8
	V1L351	151-3	5	19000101	***	9.20	1.304	7 - 10	9.20	0.447	8 - 10	9.92	0.045	9.8 - 10	7.00	1.000	5 - 9
		152	5	19000101	***	9.40	0.548	8 - 10	8.80	0.447	8 - 10	9.88	0.045	9.8 - 10	7.20	0.837	6 - 9
		153	9	19000101	***	7.22	0.972	5 - 9	7.22	0.972	5 - 9	9.62	0.618	9 - 10	6.44	0.726	5 - 8
		155	3	19000101	***	9.33	0.577	8 - 10	8.67	0.577	8 - 10	9.90	0.000	9.9 - 9.9	7.00	1.000	5 - 9
	V1L417	151-3	30	19000101	***	9.47	0.507	9 - 10	9.33	0.606	8 - 10	9.71	1.080	8 - 10	8.00	0.587	7 - 9
		152	6	19000101	***	9.17	0.408	8 - 10	9.17	0.408	8 - 10	9.90	0.000	9.9 - 9.9	8.00	0.632	7 - 9
		152-1	15	19000101	***	9.47	0.640	8 - 10	9.40	0.507	8 - 10	9.44	1.782	6 - 10	8.00	0.378	7 - 9
		153	4	19000101	***	9.00	0.816	8 - 10	8.25	0.500	7 - 9	9.88	0.050	9.8 - 10	7.50	0.577	6 - 9
		153-1	20	19000101	***	8.80	0.616	8 - 10	8.90	0.447	8 - 10	9.89	0.049	9.8 - 10	7.55	0.605	6 - 9
		155	10	19000101	***	9.50	0.527	9 - 10	9.60	0.516	9 - 10	9.90	0.040[1]	9.8 - 10	8.00	0.289[1]	7 - 9

[1] Values adjusted from actual data per 20110511 Surveillance Panel action.

L-37 Reference Oil Targets																	
						Ridging			Rippling			Spitting			Wear		
Hardware	Pinion Batch	Oil	n	From	To	x	s	Bands	x	s	Bands	x	s	Bands	x	s	Bands
NONLUBRITED	V1L500	152-1	13	19000101	***	8.85	0.689	8 - 10	9.39	0.506	8 - 10	9.89	0.028	9.8 - 9.9	7.46	0.519	7 - 8
		155	15	19000101	***	9.07	0.594	8 - 10	9.33	0.488	8 - 10	9.84	0.124	9.6 - 10	7.47	0.516	7 - 8
	V1L686	127	9	19000101	***	7.00	2.000	3 - 10	7.56	1.236	5 - 10	9.71	0.643	9 - 10	6.67	0.500	6 - 8
		128-1	8	19000101	***	7.50	0.926	6 - 9	5.63	1.188	3 - 8	9.93	0.046	9.8 - 10	6.88	0.641	6 - 8
		129	2	19000101	***	9.50	0.707	8 - 10	10.00	0.000	10 - 10	10.00	0.000	10 - 10	8.00	1.414	5 - 10
		151-2	11	19000101	***	9.09	0.701	8 - 10	8.73	0.647	8 - 10	9.92	0.040	9.8 - 10	7.55	0.688	6 - 9
		151-3	1	19000101	***	9.00	0.000	9 - 9	8.00	0.000	8 - 8	9.90	0.000	9.9 - 9.9	7.00	0.000	7 - 7
	V1L528	134	5	19000101	***	6.40	1.673	3 - 9	8.40	0.894	6 - 10	3.80	1.483	1 - 7	5.60	0.894	4 - 8
		152-1	8	19000101	***	8.75	0.707	7 - 10	8.63	0.916	7 - 10	9.45	1.003	7 - 10	7.00	0.500	6 - 8
		152-2	8	19000101	***	8.75	0.707	7 - 10	8.63	0.916	7 - 10	9.45	1.003	7 - 10	7.00	0.500	6 - 8
		155	9	19000101	***	8.56	0.882	7 - 10	8.44	1.014	6 - 10	8.70	1.578	5 - 10	6.78	0.441	7 - 8

L-42 Reference Oil Targets						
			Effective Dates		Coast Side Pinion Scoring	
Oil	Gear Batch	N	From[1]	To[2]	$\bar{X}$	s
114	P8L123	30	3-24-95	***	23.2	8.06
	P8L205	30	7-11-96	***	23.4	5.27
	P8L737	30	3-21-95	***	20.2	6.97
114-1	P8L123[3]	--	7-2-97	***	23.2	8.06
	P8L205[3]	--	7-2-97	***	23.4	5.27
	P8L737[3]	--	7-2-97	***	20.2	6.97
	P8L327	30	6-1-99	***	25.3	4.58
115	P8L123[4]	--	2-24-03	***	23.2	8.06
	P8L205[4]	--	9-22-03	***	23.4	5.27
	P8L737[4]	--	9-22-03	***	20.2	6.97
	P8L327[4]	--	8-8-01	***	25.3	4.58
	P8L604[5]	--	11-25-02	***	25.3	4.58
116	P8L123[6]	--	9-25-05	***	22.9	4.81
	P8L205[6]	--	9-25-05	***	22.9	4.81
	P8L327[6]	--	9-25-05	***	22.9	4.81
	P8L604	9	9-25-05	***	22.9	4.81
	P4L806	32	3-20-07	***	25.1	5.49
	P8L119	10	3-22-09	***	23.0	5.49[8]
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]
117	P8T025A	10	5-29-14	***	23.0[10]	5.49[10]

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

L-60-1 Transformed Reference Oil Targets													
		Effective Dates		Viscosity[3] Increase		Pentane[4] Insolubles		Toluene[5] Insolubles		Average[6] Carbon/Varnish		Average[7] Sludge	
Oil	n	From[1]	To[2]	$\overline{X}$	s	$\overline{X}$	s	$\overline{X}$	s	$\overline{X}$	s	$\overline{X}$	s
131-3	30	6-3-94	***	4.40	0.20	0.83	0.73	-0.59	0.75	-2.08	0.42	0.53	0.49
131-4[8]	--	11-2-95	11-21-95	4.40	0.20	0.83	0.73	-0.59	0.75	-2.08	0.42	0.53	0.49
	5	11-22-95	1-10-96	4.29	0.25	0.96	0.37	-0.29	0.37	-1.95	0.70	0.39	0.45
	10	1-11-96	11-17-96	4.30	0.20	0.93	0.30	-0.23	0.34	-2.12	0.50	0.55	0.38
	23	11-18-96	9-28-97	4.30	0.17	0.90	0.33	-0.18	0.41	-2.15	0.34	0.64	0.33
	30	9-29-97	***	4.33	0.17	0.94	0.31	-0.08	0.41	-2.14	0.32	0.66	0.35
133[9]	9	8-23-00	***	4.54	0.15	1.03	0.37	0.34	0.50	0.64	0.40	0.48	0.23
143	30	6-3-94	***	3.45	0.09	0.24	0.28	-0.09	0.32	2.20	0.40	0.70	0.11
148	30	6-3-94	***	3.61	0.15	-0.95	0.39	-1.36	0.49	1.59	0.47	0.76	0.19
148-1[10]	--	3-11-02	***	3.61	0.15	-0.95	0.39	-1.36	0.49	1.59	0.47	0.76	0.19
151-2[9]	9	8-23-00	***	3.62	0.15	0.75	0.37	0.26	0.50	1.81	0.40	0.54	0.23

1 Effective for all tests completed on or after this date.
2 *** = currently in effect.
3 Transformation for Viscosity Increase is ln(VISI).
4 Transformation for Pentane Insolubles is ln(PEN).
5 Transformation for Toluene Insolubles is ln(TOL).
6 Transformation for Average Carbon/Varnish is ln(ACV/(10-ACV)).
7 Transformation for Average Sludge is -1*ln(10-ASL).
8 Initial targets based on oil 131-3.
9 Standard deviations are pooled s values for all oils except 133 and 151-2.
10 Initial targets based on oil 148.

L-60-1 Untransformed Reference Oil Targets													
		Effective Dates		Viscosity[3] Increase		Pentane[4] Insolubles		Toluene[5] Insolubles		Average[6] Carbon/Varnish		Average[7] Sludge	
Oil	n	From[1]	To[2]	$\bar{X}$[8]	s[12]	$\bar{X}$[8]	s[12]	$\bar{X}$[8]	s[12]	$\bar{X}$[8]	s[12]	$\bar{X}$[8]	s[12]
131-3	30	6-3-94	***	81.45	0.20	2.29	0.73	0.55	0.75	1.11	0.42	9.41	0.49
131-4[9]	--	11-2-95	11-21-95	81.45	0.20	2.29	0.73	0.55	0.75	1.11	0.42	9.41	0.49
	5	11-22-95	1-10-96	72.97	0.25	2.61	0.37	0.75	0.37	1.25	0.70	9.32	0.45
	10	1-11-96	11-17-96	73.70	0.20	2.53	0.30	0.79	0.34	1.07	0.50	9.42	0.38
	23	11-18-96	9-28-97	73.70	0.17	2.46	0.33	0.84	0.41	1.04	0.34	9.47	0.33
	30	9-29-97	***	75.94	0.17	2.56	0.31	0.92	0.41	1.05	0.32	9.48	0.35
133[10]	9	8-23-00	***	93.69	0.15	2.80	0.37	1.40	0.50	6.55	0.40	9.38	0.23
143	30	6-3-94	***	31.50	0.09	1.27	0.28	0.91	0.32	9.00	0.40	9.50	0.11
148	30	6-3-94	***	36.97	0.15	0.39	0.39	0.26	0.49	8.31	0.47	9.53	0.19
148-1[11]	--	3-11-02	***	36.97	0.15	0.39	0.39	0.26	0.49	8.31	0.47	9.53	0.19
151-2[10]	9	8-23-00	***	37.34	0.15	2.12	0.37	1.30	0.50	8.59	0.40	9.42	0.23

1 Effective for all tests completed on or after this date.
2 *** = currently in effect.
3 Transformation for Viscosity Increase is ln(VISI).
4 Transformation for Pentane Insolubles is ln(PEN).
5 Transformation for Toluene Insolubles is ln(TOL).
6 Transformation for Average Carbon/Varnish is ln(ACV/(10-ACV)).
7 Transformation for Average Sludge is -1*ln(10-ASL).
8 Mean values are in original units.
9 Initial targets based on oil 131-3.
10 Standard deviations are pooled s values for all oils except 133 and 151-2.
11 Initial targets based on oil 148.
12 Standard deviation derived and presented in transformed units

High Temperature Cyclic Durability Test Reference Oil Targets					
		Effective Dates		Cycles	
Oil	n	From[1]	To[2]	$\overline{X}$	s
150	27	7-1-96	10-2-97	25823	3867
150-1	11	7-1-96	3-9-99	28932	5338
150-2	--	1-26-98	9-10-06	28932[3]	5338[3]
	18	9-11-06	***	24271	4623
151	42	7-1-96	12-20-96	76254	12828
151-1	28	7-1-96	9-4-97	82584	14195
151-2	6	7-1-96	11-10-96	87277	14340
	11	11-11-96	3-17-98	81804	13416
	21	3-18-98	2-19-00	80294	11675
151-3	--	1-1-00	9-10-06	80294[4]	11675[4]
	20	9-11-06	***	74489	9662
154	--	5-13-09	***	24271	4623
155	--	2-9-06	9-10-06	80294[4]	11675[4]
	--	9-11-06	***	74489[5]	9662[5]
155-1	16	5-21-12	***	65963	15022

1 Effective for all tests completed on or after this date.
2 *** = currently in effect.
3 Targets based on oil 150-1.
4 Targets based on oil 151-2.
5 Targets based on oil 151-3.

Oil Seal Compatibility Test Reference Oil Targets										
			Effective Dates		Elongation		Shore Hardness		Volume Change	
Oil	n	Elastomer	From[1]	To[2]	$\overline{X}$	s	$\overline{X}$	s	$\overline{X}$	s
160[3]	--	Polyacrylate	11-18-94	***	23.04	14.289	-1.8	1.16	0.343	0.4473
	--	Fluoroelastomer	11-18-94	***	-47.65	5.506	1.6	1.36	2.053	0.4075
160-1	144	Polyacrylate	11-18-94	***	23.04	14.289	-1.8	1.16	0.343	0.4473
	141	Fluoroelastomer	11-18-94	***	-47.65	5.506	1.6	1.36	2.053	0.4075
161[4]	--	Polyacrylate	11-18-94	***	68.88	17.850	-24.9	2.83	19.624	1.4348
	--	Fluoroelastomer	11-18-94	***	-34.57	6.989	1.6	1.30	6.199	0.7080
	--	Nitrile	11-18-94	***	10.43	10.691	-16.1	2.18	18.444	1.7057
161-1	144	Polyacrylate	11-18-94	***	68.88	17.850	-24.9	2.83	19.624	1.4348
	141	Fluoroelastomer	11-18-94	***	-34.57	6.989	1.6	1.30	6.199	0.7080
	119	Nitrile	11-18-94	***	10.43	10.691	-16.1	2.18	18.444	1.7057
162	119	Nitrile	11-18-94	***	-65.35	7.330	2.0	2.03	2.460	1.5821
168	13	Nitrile	7-7-06	2-28-09	-74.22	2.422	3.0	1.49	1.424	0.1295
	38	Nitrile	3-1-09	3-10-09	-74.52	1.599	3.0	0.79	1.326	0.1388
	38	Nitrile	3-11-09	***	-74.52	6.965[5]	3.0	1.89[5]	1.326	1.4730[5]
169	19	Polyacrylate	3-7-12	***	49.2	21.82	-16.0	2.83[6]	13.1	1.430[6]
	18	Fluoroelastomer	3-7-12	***	-39.5	6.99[6]	0.1	1.30[6]	4.4	0.71[6]
	22	Nitrile	3-7-12	***	-16.2	10.69[6]	-8.6	2.18[6]	11.8	1.710[6]

1 Effective for all tests completed on or after this date.
2 *** = currently in effect.
3 Targets based on oil 160-1.
4 Targets based on oil 161-1.
5 Standard deviation based on oil 162 (n=138).
6 Standard deviation based on oil 161-1.

APPENDIX B

HISTORY OF INDUSTRY CORRECTION FACTORS

Test Area	Effective		Condition	Correction
	From	To		
IIIF	June 13, 2010	***	Reference Tests	Adjust the Hours to 275 % Viscosity Increase by adding 10 hours.
			Non-reference Tests	Refer to Section 12.7.9.6 of Test Method D6984
IIIG	None		All Tests	None
IIIGA	None		All Tests	None
IIIGB	July 24, 2009	***	All Tests	Add 1.61 to PHOS
IVA	None		All Tests	None
VG	July 1, 2005	November 9, 2007	All tests using fuel batch TF2221LS20	Add 0.19 to AEV
				Add 2.175 to AES and divide by 1.192
				Add 0.54 to APV
				Add 0.627 to RCS and divide by 1.041
	November 10, 2007	***	All tests using fuel batch TF2221LS20	Add 0.12 to AEV
				Add 0.42 to AES
				Add 0.39 to APV
				Add 0.23 to RCS
	May 26, 2009	September 30, 2009	All tests using fuel batch XC2721NX10	Add 3.011 to AEV and divide by 1.356
				Add 1.325 to APV and divide by 1.207
	October 1, 2009	***	All tests using fuel batch XC2721NX10	Subtract 0.24 from APV
				Subtract 0.12 from AEV
	September 25, 2013	***	All tests using fuel batch AK2821NX10-1	Adjust AES by equation: $AES + e^{[(AES-5.00)(AES-9.70)]/351}$
				Adjust RAC by equation: $(RAC - 4.71)/0.49$
				Subtract 0.757 from transformed OSCR
				Add 0.18 to AEV.
VIB	None		All Tests	None
VID	None		All Tests	None
VIII	None		All Tests	None

APPENDIX B (continued)
HISTORY OF INDUSTRY CORRECTION FACTORS

Test Area	Effective		Condition	Description
	From	To		
1M-PC	None		All Tests	None
1K	None		All Tests	None
1N	May 1, 2004	September 27, 2005	All Tests	Add -1.135 to ln(TLHC+1)
	September 28, 2005	***	All Tests	Add -0.451 to ln(TLHC+1)
1P	None		All Tests	None
1R	None		All Tests	None
C13	None		All Tests	None
ISB	April 21, 2011	***	All tests using batch B tappets with batch E, F, and G cams	Multiply ATWL by 0.637; Add -9.5 to ACSW
ISB	December 11, 2011	November 12, 2012	All tests using batch C Tappets with batch H cams	Multiply ATWL by 0.637; Add -9.5 to ACSW
ISB	November 13, 2012	***	All tests using batch C tappets with batch H and J cams	Multiply ATWL by 0.711; Add -5.6 to ACSW
ISM	June 28, 2007	***	All Tests	Add +1.7 to Crosshead Wear At 3.9% Soot Add +19.1 to Injector Adjusting Screw Wear At 3.9% Soot
	March 4, 2010	***	All Tests	Add +1.3 to Crosshead Wear At 3.9% Soot
	April 30, 2011	***	All Tests	Add +2.5 to Crosshead Wear At 3.9% Soot
	November 19, 2013	***	All Tests	Add -0.200 to ln(SAIAS)
T-8	September 17, 2011	***	All Tests	Add +0.40 to Viscosity Increase at 3.8% Soot
T-8E	September 17,2011	***	All Tests	Add +0.08 to Relative Viscosity at 4.8% Soot (50% DIN Shear Loss) Add +0.09 to relative Viscosity at 4.8% Soot (100% DIN Shear Loss)
T-10A	None		All Tests	None

Test Area	Effective		Condition	Description
	From	To		
T-11	September 14, 2005	***	All Tests	Add -0.39% to Soot @ 12cSt Vis. Inc., Add 1274 cP to MRV Vis
	December 6, 2005	***	All Tests	Add -0.36% to Soot @ 12cSt Vis. Inc., Add 713 cP to MRV Vis.
	March 24, 2006	***	All Tests	Add -0.35% to Soot @ 12cSt Vis. Inc., Add 956 cP to MRV Vis.
T-12	***	***	All tests using batch R piston ring & cylinder liner hardware	Multiply Average Cylinder Liner Wear by 0.58
	***	May 18, 2011	All Tests SWTN Hardware	Multiply Average Top Ring Weight Loss by 0.95
				Multiply Average Cylinder Liner Wear by 0.86
				$\Delta Lead_{Final}$ = exp[(ln(ΔLead) x 0.95)]
				$\Delta Lead\ (250\text{-}300)_{Final}$ = exp[(ln(ΔLead 250-300) x 1.03)]
	May 19, 2011	June 4, 2012	All tests using SWTN Hardware	Multiply Average Top Ring Weight Loss by 0.92
				Multiply Average Cylinder Liner Wear by 0.83
				$\Delta Lead_{Final}$ = exp[(ln(ΔLead) x 0.92)]
				$\Delta Lead\ (250\text{-}300)_{Final}$ = exp[(ln(ΔLead 250-300) x 0.93)]
				OC = exp[(ln($OC_{100\text{-}300}$) x 0.95)]
				Multiply Average Top Ring Weight Loss by 0.92
	June 5, 2012	***	All tests using SWTN Hardware	Multiply Average Top Ring Weight Loss by 0.705
				Multiply Average Cylinder Liner Wear by 0.946
				$\Delta Lead_{Final}$ = exp[(ln(ΔLead) x 0.923)]
				$\Delta Lead\ (250\text{-}300)_{Final}$ = exp[(ln(ΔLead 250-300) x 0.956)]
				OC = exp[(ln($OC_{100\text{-}300}$) x 0.961)]
	***	***	All tests using UUXO Hardware	Multiply Average Top Ring Weight Loss by 0.849
				Multiply Average Cylinder Liner Wear by 0.566
				$\Delta Lead_{Final}$ = exp[(ln(ΔLead) x 0.797)]
				$\Delta Lead\ (250\text{-}300)_{Final}$ = exp[(ln(ΔLead 250-300) x 0.700)]
				OC = exp[(ln($OC_{100\text{-}300}$) x 0.916)]
	***	August 26, 2014	All tests using VUXO Hardware	Multiply Average Top Ring Weight Loss by 0.849
				Multiply Average Cylinder Liner Wear by 0.566
				$\Delta Lead_{Final}$ = exp[(ln(ΔLead) x 0.797)]
				$\Delta Lead\ (250\text{-}300)_{Final}$ = exp[(ln(ΔLead 250-300) x 0.700)]
				OC = exp[(ln($OC_{100\text{-}300}$) x 0.916)]

Test Area	Effective		Condition	Description
	From	To		
T-12	August 26, 2014	***	All tests using VUXO Hardware	Multiply Average Top Ring Weight Loss by 0.719
				Multiply Average Cylinder Liner Wear by 0.818
				$\Delta Lead_{Final}$ = exp[(ln(ΔLead) x 0.813)]
				$\Delta Lead\ (250\text{-}300)_{Final}$ = exp[(ln(ΔLead 250-300) x 0.710)]
				OC = exp[(ln($OC_{100\text{-}300}$) x 0.913)]
RFWT	None		All Tests	None
EOAT	None		All Tests	None

Test Area	Effective		Condition			Description
	From	To				
L-33-1			None			None
L37	20010612	***	V1L686/P4L626A Non-reference	Lubrited Ring	Canadian	Ridging add 0.9922
	20040825	***	V1L686/P4L626A Non-reference	Lubrited Pinion & Ring	Canadian	Ridging add 0.6065
	***	***	L247/T758A Non-reference	Lubrited Pinion	Canadian	Ridging add 0.5878, Pitting/Spalling add 0.7340
	***	20130514	V1L528/P4T883A Non-reference	Nonlubrited Pinion	Standard	Ridging add 0.3365, Rippling add 0.3365
					Canadian	Rippling add 0.7885
				Lubrited Pinion	Standard	Ridging add 0.3365
					Canadian	Ridging add 0.5878, Rippling add 0.5878
				Lubrited Ring	Canadian	Ridging add 0.3365
	20130515	***	V1L528/P4T883A Non-reference	Nonlubrited Pinion	Standard	Ridging add 0.3365, Rippling add 0.3365
					Canadian	Rippling add 0.7566
				Lubrited Pinion	Standard	Ridging add 0.3365
					Canadian	Ridging add 0.5878, Rippling add 0.5878
				Lubrited Ring	Canadian	Ridging add 0.3365
L-42	20140529	***	All reference oil tests using oil 117			Add 6% to pinion scoring result and add 4% to ring scoring result
L-60-1			None			None
HTCT			None			None
OSCT			None			None

APPENDIX C

HISTORY OF SEVERITY ADJUSTMENT (SA)
STANDARD DEVIATIONS

Test	Parameter	s	Effective Dates	
			From	To
Sequence IIIF	VIS80	0.0129546	20000610	20130513
	HRS	7.701	20130514	***
	APV	0.220	20000610	***
	WPD	0.658	20000610	***
	VIS60	0.17334	20011115	20130513
	VIS60	0.5*HRS SA	20130514	***
Sequence IIIG	PVIS	0.2919	20030501	***
	WPD	0.60	20030501	***
	ACLW	0.1936	20030501	20040120
		0.1903	20040121	***
Sequence IIIGA	MRV Viscosity	0.30763	20031103	20040526
Sequence IIIGB	Phos. Retention	2.33	20081112	***
Sequence IVA	ACW	9.47	19980819	20010524
		12.50	20010525	20050630
		12.52	20050701	20120208
		15.72	20120209	20120710
		14.87	20120711	***

HISTORY OF SEVERITY ADJUSTMENT (SA)
STANDARD DEVIATIONS

Test	Parameter	s	Effective Dates	
			From	To
Sequence VG	AES	0.61	19980916	19990531
		0.68	19990601	19991115
		0.55	19991116	20000524
		0.51	20000525	20001116
		0.47	20001117	20041231
		0.45	20050101	***
	RCS	0.56	19980916	19990531
		0.32	19990601	19991115
		0.28	19991116	20000524
		0.24	20000525	20001116
		0.33	20001117	20041231
		0.25	20050101	20130924
		0.56	20130925	***
	AEV	0.23	19980916	19990531
		0.10	19990601	19991115
		0.11	19991116	20000524
		0.10	20000525	20001116
		0.09	20001117	20041231
		0.10	20050101	20110728
		0.16	20110729	***
	APV	0.32	19980916	19990531
		0.26	19990601	19991115
		0.17	19991116	20000524
		0.18	20000525	20001116
		0.17	20001117	20041231
		0.20	20050101	20110728
		0.31	20110729	***
	OSCRNSLG	27.34	19980916	19990531
		18.10	19990601	19991115
		3.40	19991116	20000524
		0.828[1]	20000525	20001116
		0.742[1]	20001117	20041231
		0.793[1]	20050101	***

1 Transformation ln(OSCRNSLG + 1) adopted 20000525.

HISTORY OF SEVERITY ADJUSTMENT (SA)
STANDARD DEVIATIONS (Continued)

Test	Parameter	s	Effective Dates	
			From	To
Sequence VIB	FEI1	0.18	19980825	***
	FEI2	0.17	19980825	***
Sequence VID	FEI1	0.14	20090422	20091202
	FEI2	0.16	20090422	20091202
	FEI1	0.12	20091203	***
	FEI2	0.14	20091203	***
Sequence VIII	TBWL	3.40	19980829	19991116
		5.28	19991117	20020205
		4.80	20020206	***
	10hr. Stripped Vis.	None	--	--
1M-PC	WTD	50.5	19930914	***
	TGF	16.1	19930914	***
1K	WDK	35.6	19900506	***
	TGF	15.7	19900506	***
	TLHC	1.1	19900506	***
	OC	None	--	--
1N	WDN	27.1	19930314	***
	TGF	14.6	19930314	***
	TLHC	0.9	19930314	***
	OC	None	--	--
1P	TGC	7.740	19970219	***
	TLC	13.150	19970219	***
	AOC	0.3238	19970219	***
	WDP	57.60	19970219	***
	EOTOC	0.5177	19970219	***
1R	WDR	29.0	20010701	***
	TGC	9.70	20010701	***
	TLC	7.84	20010701	***
	IOC	1.32	20010701	***
	EOTOC	1.35	20010701	***
C13	TGC	None	--	--
	TLC	None	--	--
	OCΔ	None	--	--
	R2TC	None	--	--
ISB	Camshaft Wear	None	--	--
	Tappet Wt. Loss	None	--	--
ISM	X-Head Wear	None	--	--
	OFDP	None	--	--
	Average Sludge	None	--	--
	Adj. Screw Wear	None	--	--

HISTORY OF SEVERITY ADJUSTMENT (SA)
STANDARD DEVIATIONS (Continued)

Test	Parameter	s	Effective Dates	
			From	To
T-8	Vis. Inc. @ 3.8%	1.19	19940401	19960930
	Vis. Inc. @ 3.8%	0.93	19961001	19990131
	Vis. Inc. @ 3.8%	0.90	19990201	20070524
	Vis. Inc. @ 3.8%	0.00	20070525	20110916
	Vis. Inc. @ 3.8%	0.56	20110917	***
T-8E	Rel. Vis. @ 4.8% 50% DIN Shear	0.26	19970127	20070524
	Rel. Vis. @ 4.8% 50% DIN Shear	0.00	20070525	20110916
	Rel. Vis. @ 4.8% 50% DIN Shear	0.08	20110917	***
	Rel. Vis. @ 4.8% 100% DIN Shear	0.27	20020306	20070524
	Rel. Vis. @ 4.8% 100% DIN Shear	0.00	20070525	20110916
	Rel. Vis. @ 4.8% 100% DIN Shear	0.09	20110917	***
T-10A	MRV Viscosity	511	20001201	20020115
		643	20020116	20020924
		496	20020925	20030121
		497	20030122	***
T-11	Soot@4.0 cSt Vis	0.23	20050528	20130702
	Soot@12.0 cSt Vis	0.21	20030308	20130702
	Soot@15.0 cSt Vis	0.26	20050528	20130702
	MRV Viscosity	1097	20030308	20130702
	Soot@4.0 cSt Vis	0.20	20130703	***
	Soot@12.0 cSt Vis	0.50	20130703	***
	Soot@15.0 cSt Vis	0.61	20130703	***
	MRV Viscosity	584	20130703	***
T-12	Cyl. Liner Wear	1.6	20050219	***
	Top Ring Wt. Loss	24.9	20050219	***
	Oil Consumption	0.0610	20050219	***
	ΔPB @ EOT	0.2880	20050219	***
	ΔPB 250-300 h	0.3630	20050219	***
	Cyl. Liner Wear	1.6	20050219	***
	Top Ring Wt. Loss	24.9	20050219	***
	Oil Consumption	0.0610	20050219	***
	ΔPB @ EOT	0.2880	20050219	***
	ΔPB 250-300 h	0.3630	20050219	***
RFWT	Ave. Wear	0.08	19930527	19941016
	Ave. Wear	0.05	19941017	19950625
	Ave. Wear	0.04	19950626	***
EOAT	Average Aeration	0.25	19990101	***
T-12A	MRV Viscosity	331	20100216	***

HISTORY OF SEVERITY ADJUSTMENT (SA)
STANDARD DEVIATIONS (Continued)

Test	Parameter	s	Effective Dates	
			From	To
L-33-1	Rust	0.350	20020611	***
L-37 Nonlubrited	Pinion Ridging	0.666	19000101	***
	Pinion Rippling	0.557	19000101	***
	Pinion Spitting	0.847	19000101	***
	Pinion Wear	0.713	19000101	***
L-37 Lubrited	Pinion Ridging	1.430	19000101	***
	Pinion Rippling	0.476	19000101	***
	Pinion Spitting	0.579	19000101	***
	Pinion Wear	0.519	19000101	***
L-42	% Scoring	None	--	--
L-60-1	Vis. Inc.	0.15	19940603	20050420
		0.08	20050421	***
	Pentane	0.73	19940603	20050420
		0.20	20050421	***
	Carbon/Varnish	0.45	19940603	20050420
		0.44	20050421	***
	Sludge	0.16	19940603	***
	Toluene	0.75	19940603	20050420
		0.34	20050421	***
HTCT	Cycles	None	--	--
OSCT	Elongation	None	--	--
	Shore Hardness	None	--	--
	Volume Change	None	--	--

APPENDIX D
REFERENCE OIL VISCOSITY GRADES

Oil	SAE Viscosity Grade[1]
112	90
113	90
114	90
115	80W-90
116	80W-90
117	80W-90
121	90
123	90
127	80W-90
128	80W-90
129	90
131	90
133	85W-140
134	80W-90
143	80W-90
148	80W-90
150	80W-90
151	80W-90
152	75W-90
153	75W-90
154	90
155	90
160	80W-90
161	75W-90
162	80W-90
168	80W-90
169	75W-90
433	5W-30
434	5W-30
435	5W-20
438 (538)	5W-20
539	10W-30
540 (GF5A)	5W-20
541 (GF5D)	10W-30
542 (GF5X)	0W-20
704	10W-30
809	15W-40
810	15W-40
811	15W-40
820 (PC-9A)	15W-40
821 (PC10E)	15W-40
822	15W-40
830 (PC-9E)	15W-40
831 (PC10B)	15W-40
873	40
925	5W-30
940	5W-30
1004	15W-40
1005	15W-40

REFERENCE OIL VISCOSITY GRADES (continued)

Oil	SAE Viscosity Grade[1]
1006	5W-30
1007	5W-30
1008	5W-30
1009	5W-30
1010	5W-20

[1] Viscosity grade applies to all subsequent reblends.

APPENDIX E

APPLYING SEVERITY ADJUSTMENTS

In order to adjust non-reference oil test results for laboratory or stand severity, an exponentially weighted, moving average technique (EWMA) is applied to standardized calibration test results. See Section 1.A.3 of this document for an explanation.

When the EWMA laboratory or stand (for stand based test areas) chart action limit for severity is exceeded, a severity adjustment is calculated and applied to all subsequent non-reference oil tests. The following table lists the laboratory (or stand) EWMA severity alarm limit for all tests in the current LTMS. Alarm limits are calculated by the formula listed in Section 1.A.3.

Test Type	Alarm Level	Parameter(s)	Alarm Limit
IIIF	Laboratory	All	±0.653
IIIG	Laboratory	All	±0.550
IIIGA	Laboratory	All	±0.550
IIIGB	Laboratory	All	±0.550
IVA	Laboratory	All	±0.600
VG	Laboratory	All	±0.653
VIB	Stand	All	±0.000 (Continuous)
VID	Stand	All	±0.000 (Continuous)
VIII	Laboratory	TBWL	±0.600
1M-PC	Laboratory	All	±0.653
1K	Laboratory	WTD,TGF,TLHC	±0
1N	Laboratory	WTD,TGF,TLHC	±0.653
1P	Laboratory	All	±0.653
1R	Laboratory	All	±0.653
C13	None	None	None
ISB	None	None	None
ISM	None	None	None
T-8/T-8E	Laboratory	All	±0.653
T-10A	Laboratory	All	±0.600
T-11	Laboratory	All	±0.653
T-12	Laboratory	All	±0.653
RFWT	Laboratory	All	±0.600
EOAT	Stand	All	±0.000 (Continuous)
L-33-1	Laboratory	All	±0.823
L-37	Stand	All	±0.653
L-42	None	None	None
L-60-1	Stand	All	±0.653
HTCT	None	None	None
OSCT	None	None	None

Severity Adjustment Calculation Procedure:

Round Z_i to three decimal places.

If Z_i exceeds Alarm Limit shown, calculate the Severity Adjustment (SA) as follows:

$$SA = -1*(Z_i)*s_{SA}$$

where s_{SA} = specified severity adjustment standard deviation for each parameter as shown in each test area section.

Round the SA value, using the method specified in Practice E 29, to the precision level specified in the test area data dictionary. Add the SA to the test result in the appropriate Units of Measure.

EXAMPLES:

Non-transformed Result-Laboratory Level, Sequence IID, Average Engine Rust (AER)

If the absolute value of the EWMA exceeds 0.600, apply a severity adjustment to subsequent non-reference oil results. The following example illustrates the use of the EWMA in determining the application of a severity adjustment.

$$Z_i = (Lambda)*Y_i + (1-Lambda)*Z_{i-1}$$

For this example, Z_{i-1} is 0.572 and Y_i is 1.469. Lambda for the Sequence IID test area is 0.2. Applying these values to the Z_i equation yields the following:

$$Z_i = 0.2*1.469 + (1-0.2)*0.572 = 0.7514.$$

This result is then rounded to three decimal places, which gives a Z_i value of 0.751. Since the absolute value of Z_i (0.751) is > 0.600, then subsequent non-reference oil tests will be severity adjusted. This is accomplished by multiplying –1 times the Z_i value and multiplying this result by the severity adjustment standard deviation shown in Section 2. In this case, that value is 0.12, and results in a severity adjustment of –1*0.751*0.12 = -0.09. All subsequent non-reference oil tests will have their AER values adjusted by adding –0.09 to the AER result. This severity adjustment will remain in effect until another reference oil test is completed at this laboratory. At that time, a new Z_i value will be calculated.

Transformed Result-Laboratory Level, 1N, Top Land Heavy Carbon (TLHC)

For transformed results, a severity adjustment must be applied to the non-reference oil result in transformed units, then converted back to reported units. The following is an example of the severity adjustment calculation and the application of this severity adjustment to a non-reference oil result.

$$Z_i = (Lambda)*Y_i + (1-Lambda)*Z_{i-1}$$

For this example, Z_{i-1} = -0.456 and Y_i = -1.665. Lambda for the laboratory EWMA severity control chart is 0.2. Applying these values to the Z_i equation yields the following:

$$Z_i = 0.2*-1.665 + (1-0.2)*-0.456 = -0.6978$$

This result is then rounded to three decimal places, which gives a Z_i value of –0.698. Since the absolute value of Z_i (0.698) is > 0.653, then subsequent non-reference oil tests will be severity adjusted. This is accomplished by multiplying –1 times the Z_i value and multiplying this result by the severity adjustment standard deviation shown in Section 10. In this case, that value is 0.9 and results in a severity adjustment of –1*-0.698*0.9 = 0.628. All subsequent non-reference oil tests will have their TLHC values adjusted by adding 0.628 to the TLHC result, in transformed units. This severity adjustment will remain in effect until another reference oil test is completed at this laboratory. At that time, a new Z_i value will be calculated. To illustrate the application of a severity adjustment to a parameter which has a transformation, it is necessary to transform the non-reference oil result, apply the severity adjustment, and convert the result back to reported units. The following describes this process using the values derived above.

At the completion of a laboratory's last reference oil test, it has been determined that a severity adjustment for Top Land Heavy Carbon is needed. A subsequent non-reference oil test is completed yielding 0% Top Land Heavy Carbon. To severity adjust the non-reference oil test result, it must first be converted to transformed units. This is done by adding 1.0 to the result and then taking the natural log of the sum. This results in a value of 0 in transformed units. Add the previous paragraph's adjustment of 0.628 to 0. This sum of 0.628 is the non-reference oil test's severity adjusted result in transformed units. To convert back to original units, calculate the anti-log of the transformed value and subtract 1 from the result ($e^{0.628} – 1$). This yields a value of 0.8738 in original units (%).

APPENDIX F
GUIDELINES FOR DEVELOPING REFERENCE OIL TARGETS – B.03 TESTS

The following are guidelines for developing reference oil targets for B.03 tests. Each Surveillance Panel has discretion over the final process for developing targets. Past experience has been that when new hardware and/or procedural changes are introduced that may influence test severity and/or precision, a test matrix is conducted. The guidelines below are to be used for the sole purpose of developing LTMS targets once the matrix results are approved.

Approval Matrix Design

A minimum of five operationally valid tests should be obtained on each reference oil. Note that five operationally valid tests are considered a minimum. Every effort should be made to develop a matrix design that avoids a prolonged target generation period. For test areas that utilize two or more hardware types (such as the L-37), this requirement should be duplicated on each hardware type. All matrix tests are to be run on calibrated stands. The testing is to be evenly distributed among the participating laboratories. Laboratories/stands participating in the matrix should have little bias and be in control for precision.

Reference Oil Target Mean

Reference oil means used for LTMS charting purposes are to be determined from operationally valid test results from the approval matrix. Where a laboratory or stand shows significant bias, results are to be corrected utilizing severity adjustments.

Reference Oil Target Standard Deviation

Reference oil standard deviations used for LTMS charting purposes are to be determined as follows:

If the n-size of the matrix data on a specific reference oil is less than 15:

> Calculate a pooled standard deviation utilizing existing LTMS data. Once 15 operationally valid results are obtained, update the reference oil statistics using a pooled standard deviation.

If the n-size is 15 or greater:

> Calculate a pooled standard deviation of the matrix results.

Reference Oil Target Updates

Reference oil targets are updated @ 10, 20, and 30 tests. Updated means at 20 and 30 should not differ by more than 0.25s from the 10 test targets. Where 0.25s is exceeded, a thorough investigation as to the cause should take place before the updated targets are implemented. Results from new labs or stands entering the LTMS should not be used for target updates. Targets are frozen at 30 tests. Reference oil assignment should be equally weighted amongst all reference oils until 15 tests are received on each reference oil.

APPENDIX G

GUIDELINES FOR DEVELOPING REFERENCE OIL TARGETS AND SEVERITY ADJUSTMENT STANDARD DEVIATIONS – B.01 & B.02 TESTS

The following are guidelines for developing reference oil targets and severity adjustment standard deviations for B.01 and B.02 tests. Each surveillance panel has discretion over the final process used for their specific test.

Initial Reference Oil Targets

The initial target means and standard deviations for a reference oil should be based on a data set of operationally valid tests run on ASTM calibrated stands. The number of tests needed to establish initial targets is left to the judgment of the surveillance panel; however, every effort should be made to obtain at least five (5) tests. When laboratory bias exists, test results in the target data set should be severity adjusted prior to calculating targets. Target values should be expressed in the metric, i.e. original or transformed units, deemed appropriate by the surveillance panel.

Reference Oil Target Updates

A surveillance panel has the discretion to update reference oil targets at any time. At a minimum, targets for each reference oil should be updated when 10, 20, and 30 tests have been completed. When laboratory bias exists, test results in the target data set should be severity adjusted prior to calculating targets.

Severity Adjustment Standard Deviations

Severity Adjustment (SA) standard deviations should be calculated by pooling the standard deviations of reference oils performing at or near the pass/fail limits for non-reference oils, as specified by the surveillance panel. The data sets used to calculate SA standard deviations should be the same data sets used to calculate reference oil targets. Whenever targets are updated for a reference oil used in calculating SA standard deviations, the SA standard deviations should also be updated.