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.

Table of Contents

Table of Contents

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 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. Shewhart Chart of Prediction Error

A. Control Chart Construction

This section outlines the construction of the six 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: $0 \leq \text{LAMBDA} \leq 1$,
$Z_0 = 0$ (An alternate, fast start Z_0 could be indicated for a specific test. Section 4.0 under the specific test area will denote this option)

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. Prediction Error from EWMA

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

$e_i = Y_i - Z_{i-1}$

where: Y_i = Standardized test result at test order *i*.
Z_{i-1} = EWMA of the standardized test result at test order i-1.

The following are the control chart limits for the Prediction Error from the EWMA to determine whether a severity adjustment can be applied (e_i is plotted against completion date order):

± Level 1
± Level 2
± Level 3

Where Limit 1, Limit2, and Limit3 are constants that **c**over situations where test severity can be considered within an acceptable prediction level.

Anytime a Level 3 limit is exceeded an Excessive Influence analysis must be performed. After a Level 3 alarm is exceeded an additional test must be conducted in the severity adjustment entity that triggered the alarm. Do not update severity adjustments until after the Excessive Influence analysis is completed.

The following comparison determines whether the value of Y_i is modified to limit its influence on LTMS. Y_{i+1} is the next completed reference in the severity adjustment entity after the Level 3 alarm:

i) If $|Y_i - Y_{i+1}| \leq e_i$ Level 3 limit, then Y_i is equal to the value originally determined.

ii) If $Y_i > Z_{i-1}$ and $Y_i - Y_{i+1} > e_i$ Level 3 limit, then let
$Y_i = e_i$ level 3 limit + Z_{i-1}.

iii) If $Y_i \leq Z_{i-1}$ and $Y_i - Y_{i+1} < -e_i$ Level 3 limit, then let
$Y_i = -e_i$ Level 3 limit + Z_{i-1}.

iv) If none of i), ii), or iii) is true, then Y_i is equal to the value originally determined.

Where: i = test that originally triggered Level 3 alarm,
i-1 = test prior to alarm trigger, and
i+1 = test immediately following alarm trigger.

Once the proper Y_i value has been determined, update the charts. Confirm calculations with the TMC. The laboratory and the TMC maintain a record of the modification.

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

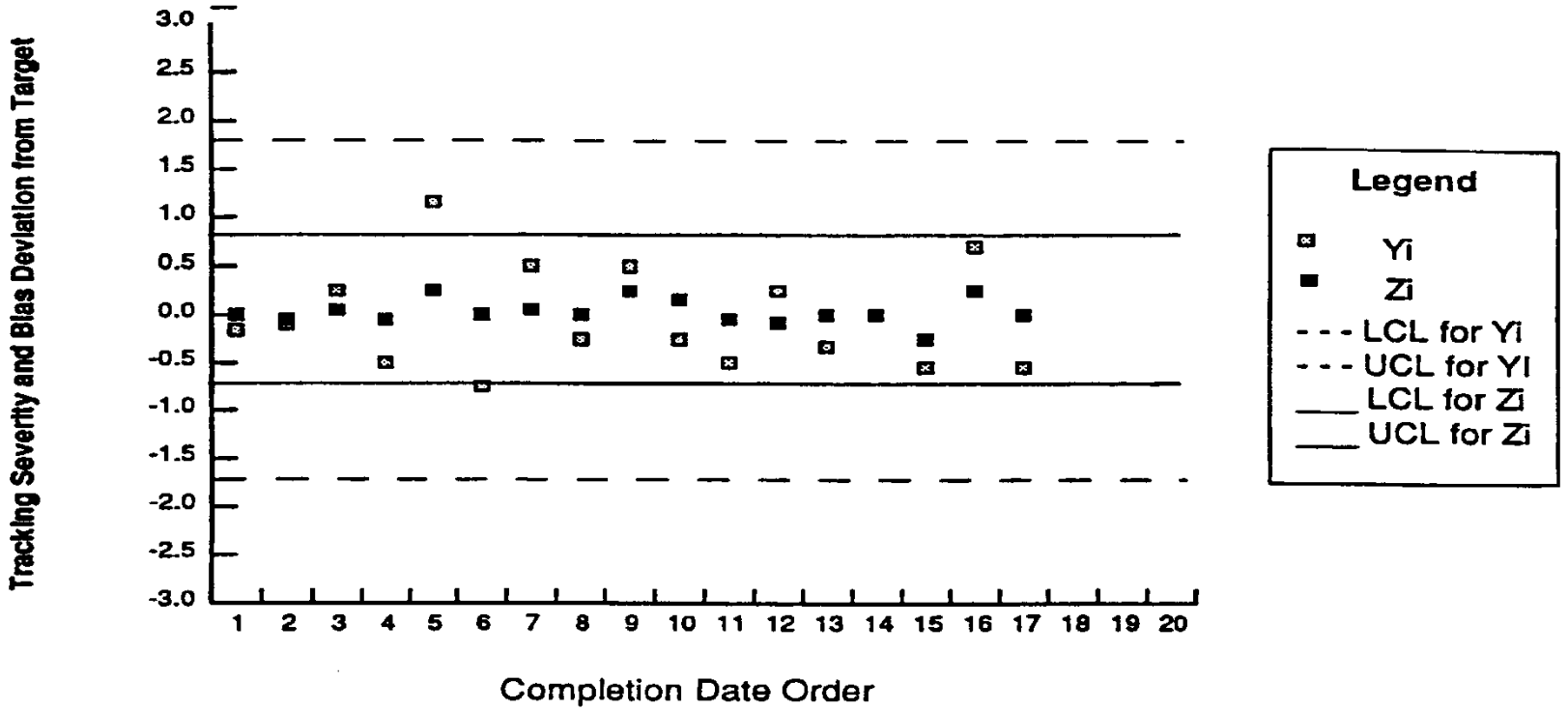
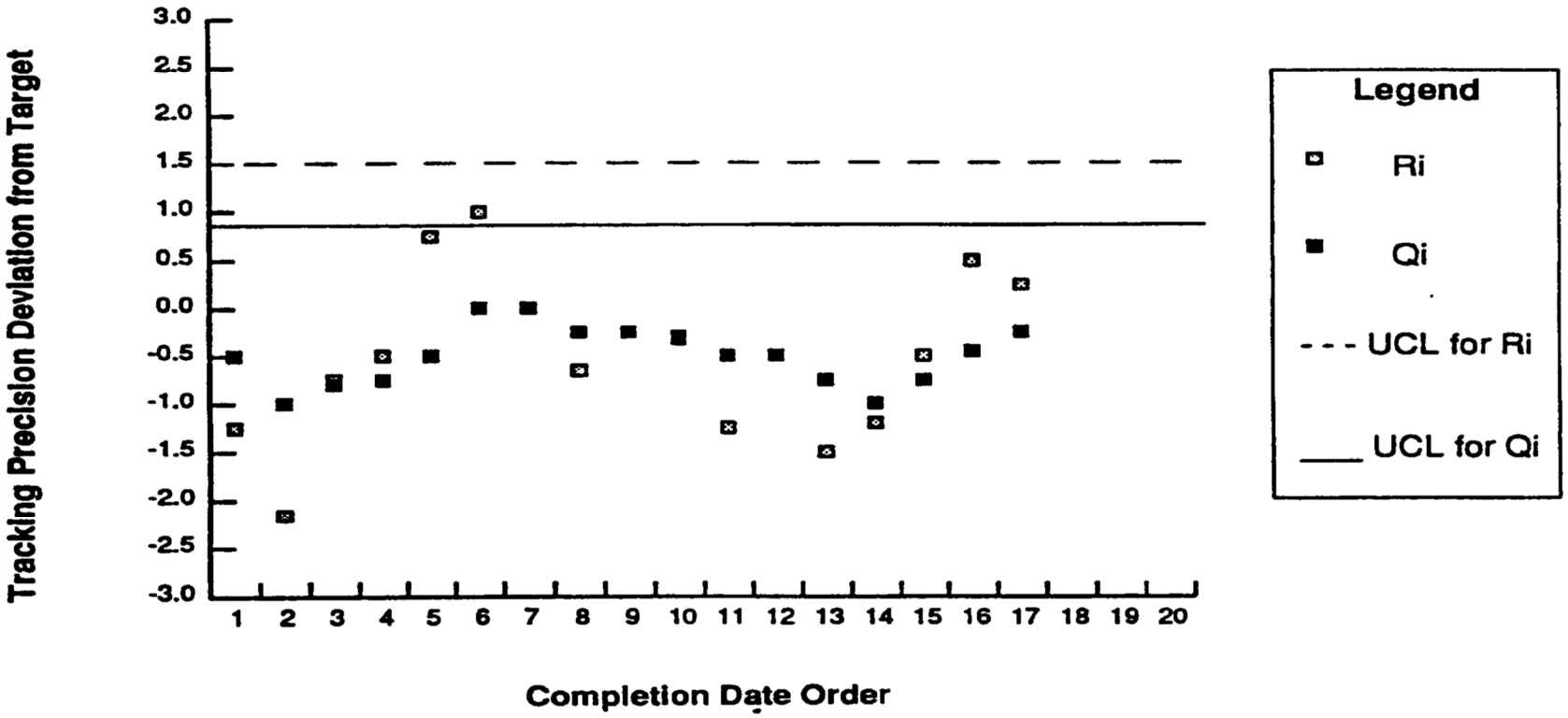


Exhibit III:
Example Charts for Precision Data
Obtained from Exhibit I

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 and EWMA 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 IIIH LTMS Requirements

The following are the specific IIIH calibration test requirements.

A. Reference Oils and Critical Performance Criteria

The critical performance criteria are Percent Viscosity Increase (PVIS), and Weighted Piston Deposits (WPD). The reference oils required for test stand and test laboratory referencing are reference oils accepted by the ASTM Sequence III Surveillance Panel. The means and standard deviations for the current reference oils for each critical performance criterion are presented below.

Percent Viscosity Increase (PVIS)
Unit of Measure: ln(PVIS)
CRITICAL PARAMETER

Reference Oil	Mean	Standard Deviation
434-2	4.7191	0.4310
434-3	5.7602	0.5845
436	3.3289	0.4005
438-1	3.9754	0.9558
438-2	3.9754	0.4950

Weighted Piston Deposits
Unit of Measure: Merits
CRITICAL PARAMETER

Reference Oil	Mean	Standard Deviation
434-2	4.16	0.70
434-3	4.16	0.42
436	4.63	0.34
438-1	3.66	0.43
438-2	3.87	0.26

Average Piston Varnish
Unit of Measure: Merits
NONCRITICAL PARAMETER

Reference Oil	Mean	Standard Deviation
434-2	9.16	0.3810
434-3	9.16	0.3000
436	9.71	0.1240
438-1	9.39	0.2760
438-2	9.39	0.2889

B. Acceptance Criteria

1. New Test Stands

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

2. Existing Test Stands

- The stand must have previously been accepted into the system by meeting the LTMS requirements.
- Existing test stands that have run an acceptable reference in the past 18 months may calibrate with 1 test.
- Following the necessary tests, check the status of the control charts and follow the prescribed actions.

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:

- Scheduled calibration tests should be conducted on reference oils 436, 434-2, and 438-1 or subsequent approved reblends in equal proportion with random assignment.

4. Control Charts

In Section 1, the construction of the control charts that constitute the Lubricant Test Monitoring System is outlined. For the IIIH, Z_0=Mean Y_i of first two operationally valid tests in the stand. The constants used for the construction of the control charts for the IIIH, 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		Stand Prediction Error	
		Severity		Severity	
Chart Level	Limit Type	Lambda	Alarm	Limit Type	Limit
Stand	Level 1	0.3	0.000	Level 1	N/A
	Level 2		±1.800	Level 2	±1.734
				Level 3	±2.066
Industry	Level 1	0.2	±0.775	--	--
	Level 2		±0.859	--	--

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 Stand chart of Prediction Error (e_i) Critical parameters only

  Level 3:

  – Immediately conduct one additional reference test in the stand that triggered the alarm. Do not update the control charts until the follow up reference test is completed and Excessive Influence (refer to Section 1.A.5) has been performed.

  Level 2:

  – The Level 2 limit applies in situations that have been pre-determined by the surveillance panel to have a potential impact on test results. These situations may include the introduction of new critical parts, fuel batches, reference oil reblends, or other test components. When these conditions have been met and a Level 2 alarm is triggered, immediately conduct one additional reference test in the stand that triggered the alarm.

- Exceed Stand EWMA of Standardized Test Result (Z_i)

Level 2 (Critical parameters only):

- Conduct one additional reference test in the stand that triggered the alarm. The stand that triggered the alarm is not qualified for non-reference tests until the Level 2 alarm is cleared.
- In instances where surveillance panel has deemed that industry-wide circumstances are impacting the Level 2 alarm, the TMC may be asked to review stand calibration status in accordance with the surveillance panel's findings.

Level 1 (All parameters):

- The Level 1 limit applies to all reference tests that are control charted, even when other alarms have been triggered. Level 1 uses Z_i to determine the stand severity adjustment (SA). Calculate the stand SA as follows and confirm the calculation with the TMC:

  Percent Viscosity Increase (ln(PVIS)): SA = $(-Z_i)$ x (0.4933)
  Weighted Piston Deposits (WPD): SA = $(-Z_i)$ x (0.35)
  Average Piston Varnish (APV): SA =(-Zi) x (0.2376)

- Exceed Industry EWMA of Standardized Test Result (Z_i)

Level 2:

- TMC informs the surveillance panel that the limit has been exceeded. The surveillance panel then investigates and pursues resolution of the alarm.

Level 1:

- The TMC investigates whether severity adjustments are adequately addressing the trend, investigates the possible causes, and communicates as appropriate with industry.

3. Sequence IIIHA LTMS Requirements

The following are the specific IIIHA calibration test requirements.

A. Reference Oils and Critical Performance Criteria

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

MRV Viscosity
Unit of Measure: ln(MRV)

Reference Oil	Mean	Standard Deviation
434-2	11.1107	0.5220
434-3[A]	---	---
436	9.7854	0.2864
438-1	9.8189	0.9132
438-2	9.8189	0.6511

[A] For oil 434-3, use Sequence IIIH PVIS Yi value as MRV Yi value

B. Acceptance Criteria

1. New Test Stands

- Stand must be calibrated according to Sequence IIIH requirements. A Sequence IIIHA test must be conducted as part of each Sequence IIIH test.
- A minimum of two (2) operationally valid calibration tests and/or matrix tests, with no Level 3 e_i or level 2 Z_i alarms after the second operationally valid test must be conducted in a new stand on any approved reference oils.
- Note that industry matrix runs may be included, as well as reference runs, at the discretion of the surveillance panel.
- Following the necessary tests, check the status of the control charts and follow the prescribed actions.

2. Existing Test Stands

- Stand must be calibrated according to Sequence IIIH requirements. A Sequence IIIHA test must be conducted as part of each Sequence IIIH test.
- Test stands in an existing test lab that have not run an acceptable reference in the past two years, may calibrate with one test provided e_i Level 1 limits are not exceeded. Otherwise a second test is required for calibration.

- Following the necessary tests, check the status of the control charts and follow the prescribed actions.

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:

- Scheduled calibration tests should be conducted on reference oils 436, 434-2, and 438-1 or subsequent approved reblends in equal proportion with random assignment.

4. Control Charts

In Section 1, the construction of the control charts that constitute the Lubricant Test Monitoring System is outlined. For the IIIHA, Z_0=Mean Y_i of first two operationally valid tests in the stand. The constants used for the construction of the control charts for the IIIHA, 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		Stand Prediction Error	
		Severity		Severity	
Chart Level	Limit Type	Lambda	Alarm	Limit Type	Limit
Stand	Level 1	0.3	0.000	Level 1	N/A
	Level 2		±1.800	Level 2	±1.734
				Level 3	±2.066
Industry	Level 1	0.2	±0.775	--	--
	Level 2		±0.859	--	--

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 Stand chart of Prediction Error (e_i)

  Level 3:

  – Immediately conduct one additional reference test in the stand that triggered the alarm. Do not update the control charts until the follow up reference test is completed and Excessive Influence (refer to Section 1.A.5) has been performed.

  Level 2:

  – The Level 2 limit applies in situations that have been pre-determined by the surveillance panel to have a potential impact on test results. These situations may include the introduction of new critical parts, fuel batches, reference oil reblends, or other test components. When these conditions have been met and a Level 2 alarm is triggered, immediately conduct one additional reference test in the stand that triggered the alarm.

- Exceed Stand EWMA of Standardized Test Result (Z_i)

  Level 2:

  – Immediately conduct one additional reference test in the stand that triggered the alarm. The stand that triggered the alarm is not qualified for non-reference tests until the Level 2 alarm is cleared.
  – In instances where surveillance panel has deemed that industry-wide circumstances are impacting the Level 2 alarm, the TMC may be asked to review stand calibration status in accordance with the surveillance panel's findings.

  Level 1:

  – The Level 1 limit applies to all reference tests that are control charted, even when other alarms have been triggered. Level 1 uses Z_i to determine the stand severity adjustment (SA). Calculate the stand SA as follows and confirm the calculation with the TMC:

    MRV Apparent Viscosity (ln(MRV)): $SA = (-Z_i) \times (0.4538)$

- Exceed Industry EWMA of Standardized Test Result (Z_i)

  Level 2:
  – TMC informs the surveillance panel that the limit has been exceeded. The surveillance panel then investigates and pursues resolution of the alarm.

  Level 1:
  – The TMC investigates whether severity adjustments are adequately addressing the trend, investigates the possible causes, and communicates as appropriate with industry.

4. Sequence IIIHB LTMS Requirements

The following are the specific IIIHB calibration test requirements.

A. Reference Oils and Critical Performance Criteria

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

PHOSPHOROUS RETENTION
Unit of Measure: Percent

Reference Oil	Mean	Standard Deviation
434-2	79.95	1.58
434-3	79.95	1.58
436	94.15	2.02
438-1	78.92	1.54
438-2	78.92	1.54

B. Acceptance Criteria

1. New Test Stands

- Stand must be calibrated according to Sequence IIIH requirements. A Sequence IIIHB test must be conducted as part of each Sequence IIIH test.
- A minimum of two (2) operationally valid calibration tests and/or matrix tests, with no Level 3 e_i or level 2 Z_i alarms after the second operationally valid test must be conducted in a new stand on any approved reference oils.
- Note that industry matrix runs may be included, as well as reference runs, at the discretion of the surveillance panel.
- Following the necessary tests, check the status of the control charts and follow the prescribed actions.

2. Existing Test Stands

- Stand must be calibrated according to Sequence IIIH requirements. A Sequence IIIHB test must be conducted as part of each Sequence IIIH test.
- Test stands in an existing test lab that have not run an acceptable reference in the past two years, may calibrate with one test provided e_i Level 1 limits are not exceeded. Otherwise a second test is required for calibration.

- Following the necessary tests, check the status of the control charts and follow the prescribed actions.

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:

- Scheduled calibration tests should be conducted on reference oils 436, 434-2, and 438-1 or subsequent approved reblends in equal proportion with random assignment.

4. Control Charts

In Section 1, the construction of the control charts that constitute the Lubricant Test Monitoring System is outlined. For the IIIHB, Z_0=Mean Y_i of first two operationally valid tests in the stand. The constants used for the construction of the control charts for the IIIHB, 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		Stand Prediction Error	
		Severity		Severity	
Chart Level	Limit Type	Lambda	Alarm	Limit Type	Limit
Stand	Level 1	0.3	0.000	Level 1	N/A
	Level 2		±1.800	Level 2	±1.734
				Level 3	±2.066
Industry	Level 1	0.2	±0.775	--	--
	Level 2		±0.859	--	--

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 Stand chart of Prediction Error (e_i)

  Level 3:

  – Immediately conduct one additional reference test in the stand that triggered the alarm. Do not update the control charts until the follow up reference test is completed and Excessive Influence (refer to Section 1.A.5) has been performed.

  Level 2:

  – The Level 2 limit applies in situations that have been pre-determined by the surveillance panel to have a potential impact on test results. These situations may include the introduction of new critical parts, fuel batches, reference oil reblends, or other test components. When these conditions have been met and a Level 2 alarm is triggered, immediately conduct one additional reference test in the stand that triggered the alarm.

- Exceed Stand EWMA of Standardized Test Result (Z_i)

  Level 2:

  – Immediately conduct one additional reference test in the stand that triggered the alarm. The stand that triggered the alarm is not qualified for non-reference tests until the Level 2 alarm is cleared.
  – In instances where surveillance panel has deemed that industry-wide circumstances are impacting the Level 2 alarm, the TMC may be asked to review stand calibration status in accordance with the surveillance panel's findings.

  Level 1:

  – The Level 1 limit applies to all reference tests that are control charted, even when other alarms have been triggered. Level 1 uses Z_i to determine the stand severity adjustment (SA). Calculate the stand SA as follows and confirm the calculation with the TMC:

    Phosphorous Retention: $SA = (-Z_i) \times (1.53)$

- Exceed Industry EWMA of Standardized Test Result (Z_i)

  Level 2:
  – TMC informs the surveillance panel that the limit has been exceeded. The surveillance panel then investigates and pursues resolution of the alarm.

  Level 1:
  – The TMC investigates whether severity adjustments are adequately addressing the trend, investigates the possible causes, and communicates as appropriate with industry.

5. 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) $SA = (-Z_i) * (14.87)$

  - 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.

6. Sequence IVB LTMS Requirements

The following are the specific Sequence IVB calibration test requirements.

A. Reference Oils and Critical Performance Criteria

The critical parameters are Average Volume Loss Intake Bucket Lifter (AVLI) and Iron at End of Test (FeWMEOT). The reference oils required for test stand and test laboratory referencing are reference oils accepted by the ASTM Sequence IVB Surveillance Panel. The means and standard deviations for the current reference oils for each critical performance criterion are presented below.

Average Volume Loss Intake Bucket Lifter
Unit of Measure: sqrt(AVLI)

Reference Oil	Mean	Standard Deviation
300	1.3931	0.2230
1011	1.2538	0.1932
1011-1	1.2538	0.1847
1012	1.1543	0.1847

End of Test Iron
Unit of Measure: ln(FeWMEOT)

Reference Oil	Mean	Standard Deviation
300	5.2645	0.3842
1011	5.0266	0.3508
1011-1	5.0266	0.3508
1012	4.8344	0.3747

A. Acceptance Criteria

1. New Test Stands

- A minimum of two (2) operationally valid calibration tests and/or matrix tests, with no Level 3 e_i or level 2 Z_i alarms after the second operationally valid test must be conducted in a new stand on any approved reference oils.

- Note that industry matrix runs may be included, as well as reference runs, at the discretion of the surveillance panel.

- Following the necessary tests, check the status of the control charts and follow the prescribed actions.

2. Existing Test Stands

- Previously calibrated test stands that have not run an acceptable reference test for two reference periods, may calibrate with one test provided e_i Level 1 limits are not exceeded. Otherwise a second test is required for calibration.

- Following the necessary tests, check the status of the control charts and follow the prescribed actions.

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:

- Scheduled calibration tests should be conducted on reference oils 300, 1011, and 1012 or subsequent approved reblends in equal proportion with random assignment.

4. Control Charts

In Section 1, the construction of the control charts that constitute the Lubricant Test Monitoring System is outlined. For the Sequence IVB, Z_0=Mean Y_i of first two operationally valid tests in the stand. The constants used for the construction of the control charts for the Sequence IVB, 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		Stand Prediction Error	
		Severity		Severity	
Chart Level	Limit Type	Lambda	Alarm	Limit Type	Limit
Stand (AVLI)	Level 1	0.3	0.000	Level 1	±1.351
	Level 2		±1.800	Level 2	±1.734
				Level 3	±2.066
Stand (FeWMEOT)	Level 1	0.2	0.000	Level 1	±1.351
	Level 2		±1.800	Level 2	±1.734
				Level 3	±2.066
Industry	Level 1	0.2	±0.775	--	--
	Level 2		±0.859	--	--

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 Stand chart of Prediction Error (e_i)

  Level 3:

  – Immediately conduct one additional reference test in the stand that triggered the alarm. Do not update the control charts until the follow up reference test is completed and Excessive Influence (refer to Section 1.A.5) has been performed.

  Level 2:

  – The Level 2 limit applies in situations that have been pre-determined by the surveillance panel to have a potential impact on test results. These situations may include the introduction of new critical parts, fuel batches, reference oil reblends, or other test components. When these conditions have been met and a Level 2 alarm is triggered, immediately conduct one additional reference test in the stand that triggered the alarm.

- Exceed Stand EWMA of Standardized Test Result (Z_i)

  Level 2:

  – Immediately conduct one additional reference test in the stand that triggered the alarm. The stand that triggered the alarm is not qualified for non-reference tests until the Level 2 alarm is cleared.
  – In instances where surveillance panel has deemed that industry-wide circumstances are impacting the Level 2 alarm, the TMC may be asked to review stand calibration status in accordance with the surveillance panel's findings.

  Level 1:

  – The Level 1 limit applies to all reference tests that are control charted, even when other alarms have been triggered. Level 1 uses Z_i to determine the stand severity adjustment (SA). Calculate the stand SA as follows and confirm the calculation with the TMC:

    Average Volume loss Intake (sqrt(AVLI)): $SA = (-Z_i) \times (0.2003)$
    End of Test Iron (ln(FEWMEOT)): $SA = (-Z_i) \times (0.3688)$

- Exceed Industry EWMA of Standardized Test Result (Z_i)

  Level 2:

  – TMC informs the surveillance panel that the limit has been exceeded. The surveillance panel then investigates and pursues resolution of the alarm.

  Level 1:

  – TMC informs the surveillance panel that the limit has been exceeded. The surveillance panel then investigates and pursues resolution of the alarm.

  – The TMC investigates whether severity adjustments are adequately addressing the trend, investigates the possible causes, and communicates as appropriate with industry.

7. VH LTMS Requirements

The following are the specific VH calibration test requirements.

A. Reference Oils and Critical Performance Criteria

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

AVERAGE ENGINE SLUDGE (AES)
Unit of Measure: Merits

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

ROCKER COVER SLUDGE (RAC)
Unit of Measure: ln(10-RAC)

Reference Oil	Mean	Standard Deviation
931	0.2283	0.5715
940	0.8041	0.2340
1011	-0.5294	0.1924
1011-1	-0.5294	0.1924

AVERAGE ENGINE VARNISH (AEV50)
Unit of Measure: Merits

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

AVERAGE PISTON VARNISH (APV50)
Unit of Measure: Merits

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

NUMBER OF HOT STUCK RINGS
Unit of Measure: Count

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

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

B. Acceptance Criteria

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

   a. The first two stands in a laboratory

   - A minimum of two (2) operationally valid calibration tests and/or matrix tests, with no Level 3 e_i alarms must be conducted in a new laboratory on any approved reference oils.

   - Note that industry matrix runs may be included, as well as reference runs, at the discretion of the surveillance panel.

   - Following the necessary tests, check the status of the control charts and follow the prescribed actions

   b. Third and subsequent stands in a laboratory

   - New test stands in an existing lab may calibrate with one test provided e_i Level 1 limits are not exceeded. Otherwise a second test is required for calibration.

   - For an existing test stand in an existing lab run one test.

   - Following the necessary tests, check the status of the control charts and follow the prescribed actions

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 oils 940, 1009 and 1011 or subsequent approved reblends in equal proportion with random assignment.

4. Control Charts

In Section 1, the construction of the control charts that constitute the Lubricant Test Monitoring System is outlined. For the VH, Z_0=Mean Y_i of first three operationally valid tests in the laboratory. The constants used for the construction of the control charts for the VH, 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		Laboratory Prediction Error	
		Severity		Severity	
Chart Level	Limit Type	Lambda	Alarm	Limit Type	Limit
Lab	Level 1	0.3	0.000	Level 1	±1.351
	Level 2		±1.800	Level 2	±1.734
Industry	Level 1	0.2	±0.775	Level 3	±2.066
	Level 2		±0.859	--	--

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 Laboratory chart of Prediction Error (e_i)

  Level 3:

  – Immediately conduct one additional reference test in the stand that triggered the alarm. Do not update the control charts until the follow up reference test is completed and the Excessive Influence (refer to Section 1.A.5) has been performed.

Level 2:

– The Level 2 limit applies in situations that have been pre-determined by the surveillance panel to have a potential impact on test results. These situations may include the introduction of new critical parts, fuel batches, reference oil reblends, or other test components. When these conditions have been met and a Level 2 alarm is triggered, immediately conduct one additional reference test in the stand that triggered the alarm.

Level 1:

– The Level 1 limit also applies to new stands in an existing test lab or a previously calibrated stand that has not been calibrated for two reference periods and is attempting to calibrate again. The stand can calibrate with one test if the Level 1 limits are not exceeded. Otherwise, immediately conduct another reference test in the stand.

- Exceed Laboratory EWMA of Standardized Test Result (Z_i)

Level 2:

– Immediately conduct one additional reference test in the engine-stand that triggered the alarm. Do not update the severity adjustments until the Level 2 alarm is cleared. The engine-stand that triggered the alarm is not qualified for non-reference tests until the Level 2 alarm is cleared.
– In instances where surveillance panel has deemed that industry-wide circumstances are impacting the Level 2 alarm, the TMC may be asked to review engine-stand calibration status in accordance with the surveillance panel's findings.

Level 1:

– The Level 1 limit applies to all reference tests that are control charted, even when other alarms have been triggered. Level 1 uses Z_i to determine the laboratory severity adjustment (SA). Calculate the laboratory SA as follows and confirm the calculation with the TMC:

RAC (ln(10-RAC)):	$SA = (-Z_i) \times (0.2194)$
AES:	$SA = (-Z_i) \times (0.50)$
AEV50:	$SA = (-Z_i) \times (0.25)$
APV50:	$SA = (-Z_i) \times (0.53)$

- Exceed Industry EWMA of Standardized Test Result (Z_i)

Level 2:

– TMC informs the surveillance panel that the limit has been exceeded. The surveillance panel then investigates and pursues resolution of the alarm.

Level 1:

– The TMC investigates whether severity adjustments are adequately addressing the trend, investigates the possible causes, and communicates as appropriate with industry.

8. Sequence IX LTMS Requirements

The following are the specific Sequence IX calibration test requirements.

A. Reference Oils and Critical Performance Criteria

The critical performance criteria is Average Number of Preignitions (AVPIE). Additionally, an upper limit is set on Maximum Pre-ignition events. The reference oils required for test stand and test laboratory referencing are reference oils accepted by the ASTM Sequence IX Surveillance Panel. The means and standard deviations for the current reference oils for each critical performance criterion are presented below.

Average Number of Preignitions (AVPIE)
Unit of Measure: Square Root (AVPIE+0.5)

Reference Oil	Mean	Standard Deviation
221	3.3819	0.3775
221-1	3.3819	0.3775
224	2.0445	0.3775
224-1	2.0445	0.3775
224-2	2.0445	0.3775

Maximum Number of Preignitions (MAXPIE)
Unit of Measure: Square Root (MAXPIE+0.5)

Reference Oil	Targets
All Oils	N/A

B. Acceptance Criteria

1. New Test Stand/Engines

- A minimum of two (2) operationally valid calibration tests, with no Level 0 e_i or Level 2 Z_i alarms after the second operationally valid test must be conducted in a new stand-engine on any approved reference oils. If the above criteria cannot be met then a minimum of three (3) operationally valid calibration tests, with no Level 3 e_i or level 2 Z_i alarms after the third operationally valid test must be conducted in a new stand-engine on any approved reference oils.

- Additionally, engines using pistons other than BB grade pistons originally installed in the engine will be required to demonstrate discrimination by meeting the criteria of less than AVPIE of 2.12 for four consecutive valid iterations on RO220 (or subsequent reblends). These results will not be used for charting purposes.

- Following the necessary tests, check the status of the control charts and follow the prescribed actions.

2. Existing Test Stand/Engine

- The stand/engine must have previously been accepted into the system by meeting the LTMS requirements
- Existing test stand-engines that have run an acceptable reference in the past 180 days may calibrate with 1 test.
- Following the necessary tests, check the status of the control charts and follow the prescribed actions.

3. Reference Oil Assignment

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

- Scheduled calibration tests should be conducted on reference oils 221 and 224 or subsequent approved reblends in equal proportion with random assignment.

4. Control Charts

In Section 1, the construction of the control charts that contribute to the Lubricant Test Monitoring System is outlined. For the Sequence IX, Z_0=Mean Y_i of all operationally valid tests in the initial stand-engine calibration sequence. The constants used for the construction of the control charts for the Sequence IX, and the response necessary in the case of control chart limit alarms, are depicted below.

LUBRICANT TEST MONITORING SYSTEM CONSTANTS

		EWMA Chart		Stand-Engine Prediction Error	
		Severity		Severity	
Chart Level	Limit Type	Lambda	Alarm	Limit Type	Limit
Stand-Engine		0.4		Level 0	±1.000
	Level 1		0.000	Level 1	±1.351
	Level 2		±1.500	Level 2	±1.734
				Level 3	±2.066
Industry	Level 1	0.2	±0.775	-	-
	Level 2		±0.859	-	-

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 and/or engine from the system.

- Exceed Stand-engine chart of Prediction Error (e_i)

  Level 3:

  – Immediately conduct one additional reference test in the stand-engine that triggered the alarm. Do not update the control charts until the follow up reference test is completed and Excessive Influence (refer to Section 1.A.5) has been performed.

  Level 2:

  – The Level 2 limit applies in situations that have been pre-determined by the surveillance panel to have a potential impact on test results. These situations may include the introduction of new critical parts, fuel batches, reference oil reblends, or other test components. When these conditions have been met and a Level 2 alarm is triggered, immediately conduct one additional reference test in the stand-engine that triggered the alarm. Evaluate the subsequent test(s) using Level 3 limit.

  Level 1:

  – The Level 1 limit applies in situations where a previously calibrated stand-engine has not been calibrated for two reference periods and is attempting to calibrate again. Immediately conduct one additional reference test in the stand-engine that triggered the alarm. Evaluate the subsequent test(s) using Level 3 limit.

  Level 0:

  – Immediately conduct one additional reference test in the stand-engine that triggered the alarm. Evaluate the subsequent test(s) using Level 3 limit.

- Exceed Stand EWMA of Standardized Test Result

  (Z_i) Level 2:

  – Conduct one additional reference test in the stand-engine that triggered the alarm. The stand-engine that triggered the alarm is not qualified for non-reference tests until the Level 2 alarm is cleared.

  – In instances where surveillance panel has deemed that industry-wide circumstances are impacting the Level 2 alarm, the TMC may be asked to review stand-engine calibration status in accordance with the surveillance panel's findings.

  Level 1:

  – The Level 1 limit applies to all reference tests that are control charted, even when other alarms have been triggered. Level 1 uses Z_i to determine the stand severity adjustment (SA). Calculate the stand SA as follows and confirm the calculation with the TMC:

  AVPIE SA = $(-Z_i)$ x (0.3775)

  MAXPIE SA = AVPIE SA

- When MAXPIE ≥ AVPIE + 1.3199

  – Conduct one additional reference test in the stand-engine that triggered the alarm. The stand-engine that triggered the alarm is not qualified for non-reference tests until the alarm is cleared.

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

- Exceed Industry EWMA of Standardized Test Result (Z_i)

  Level 2:

  – The TMC informs the surveillance panel that the limit has been exceeded. The surveillance panel then investigates and pursues resolution of the alarm.

  Level 1:

  – The TMC investigates whether severity adjustments are adequately addressing the trend, investigates the possible causes, and communicates as appropriate with industry.

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. The removal and reinstallation of the most recently calibrated engine back into the same test stand requires only a single successful calibration test, provided its previous calibration period has not expired.

9. Sequence IX Aged Oil LSPI LTMS Requirements

The following are the specific Sequence IX Aged Oil LSPI calibration test requirements.

A. Reference Oils and Critical Performance Criteria

The critical performance criteria is Average Number of Preignitions (AVPIE). The reference oils required for test stand and test laboratory referencing are reference oils accepted by the ASTM Sequence IX Surveillance Panel. The means and standard deviations for the current reference oils for each critical performance criterion are presented below.

Average Number of Preignitions (AVPIE)
Unit of Measure: Square Root (AVPIE+0.5)

Reference Oil	Mean	Standard Deviation
API01	1.6280	0.4070
API01-1	1.6280	0.4070
API02	3.4085	0.4717
API02-1	3.4085	0.4717

B. Acceptance Criteria

1. New Aging Test Stands

- A minimum of two (2) operationally valid calibration tests, with no Shewhart alarms (preferably one on each oil) and no Level 2 Z_i or Ei Level 3 alarms after the second operationally valid test must be conducted in a new Aging stand on any approved reference oils

- Following the necessary tests, check the status of the control charts and follow the prescribed actions.

2. Existing Aging Test Stand

- The Aging stand must have previously been accepted into the system by meeting the LTMS requirements

- Existing test stands that have run an acceptable reference in the past 360 days may calibrate with 1 test.

- Following the necessary tests, check the status of the control charts and follow the prescribed actions.

3. Reference Oil Assignment

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

- Scheduled calibration tests should be conducted on reference oils API01 and API02 or subsequent approved reblends in equal proportion with random assignment.

4. Control Charts

In Section 1, the construction of the control charts that contribute to the Lubricant Test Monitoring System is outlined. For the Aged Oil LSPI, Z_0=Mean Y_i of all operationally valid tests in the initial stand calibration sequence. The constants used for the construction of the control charts for the Sequence IX Aged, and the response necessary in the case of control chart limit alarms, are depicted below.

LUBRICANT TEST MONITORING SYSTEM CONSTANTS

		EWMA Chart		Stand Prediction Error		Shewhart
		Severity		Severity		Severity
Chart Level	Limit Type	Lambda	Alarm	Limit Type	Limit	Limit
	Level 1	0.2		Level 1	±1.351	±2.000
	Level 2		±1.300	Level 2	±1.734	
				Level 3	±2.066	
Industry	Level 1	0.2	±0.775	--	-	N/A
	Level 2		±0.859	-	-	

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 Aging Stand chart of Prediction Error (e_i)

Level 3:

– Immediately conduct one additional reference test in the stand that triggered the alarm. Do not update the control charts until the follow up reference test is completed and Excessive Influence (refer to Section 1.A.5) has been performed.

Level 2:

– The Level 2 limit applies in situations that have been pre-determined by the surveillance panel to have a potential impact on test results. These situations may include the introduction of new critical parts, fuel batches, reference oil reblends, or other test components. When these conditions have been met and a Level 2 alarm is triggered, immediately conduct one additional reference test in the stand that triggered the alarm. Evaluate the subsequent test(s) using Level 3 limit.

Level 1:

– The Level 1 limit applies in situations where a previously calibrated stand has not been calibrated for two reference periods and is attempting to calibrate again. Immediately conduct one additional reference test in the stand that triggered the alarm. Evaluate the subsequent test(s) using Level 3 limit.

- Exceed Stand EWMA of Standardized Test Result

(Z_i) Level 2:

– Conduct one additional reference test in the stand that triggered the alarm. The stand that triggered the alarm is not qualified for non- reference tests until the Level 2 alarm is cleared.

– In instances where surveillance panel has deemed that industry-wide circumstances are impacting the Level 2 alarm, the TMC may be asked to review stand calibration status in accordance with the surveillance panel's findings.

Exceed Stand Shewhart Alarm limit

– Conduct one additional reference test in the stand that triggered the alarm. The stand that triggered the alarm is not qualified for non- reference tests until the shewhart alarm is cleared.

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

- Exceed Industry EWMA of Standardized Test Result (Z_i)

Level 2:

– The TMC informs the surveillance panel that the limit has been exceeded. The surveillance panel then investigates and pursues resolution of the alarm.

Level 1:

– The TMC investigates whether severity adjustments are adequately addressing the trend, investigates the possible causes, and communicates as appropriate with industry.

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.

10. Sequence X LTMS Requirements

The following are the specific Sequence X calibration test requirements.

A. Reference Oils and Critical Performance Criteria

The critical parameter is Chain wear stretch (CHST). The reference oils required for test stand and test laboratory referencing are reference oils accepted by the ASTM Sequence X Surveillance Panel. The means and standard deviations for the current reference oils for each critical performance criterion are presented below.

Chain Wear Stretch
Unit of Measure: ln(CHST)

Reference Oil	Mean	Standard Deviation
270	-2.15699	0.17435
271	-2.60987	0.17537
1011	-2.08191	0.18882

B. Acceptance Criteria

3. New Test Stands

- A minimum of two (2) operationally valid calibration tests and/or matrix tests, with no Level 3 e_i or level 2 Z_i alarms after the second operationally valid test must be conducted in a new stand on any approved reference oils.

- Note that industry matrix runs may be included, as well as reference runs, at the discretion of the surveillance panel.

- Following the necessary tests, check the status of the control charts and follow the prescribed actions.

- In addition to a calibration run, labs must also pass a discrimination run on reference oil 271. The discrimination run is to be run consecutively with the calibration test sample. The discrimination run is valid for not more than 360 days from date completed. The discrimination run does not calibrate the stand, but rather confirms that the discrimination oil test result can be discriminated from the calibration oil test result when run consecutively.

4. Existing Test Stands

- Previously calibrated test stands that have not run an acceptable reference test for two reference periods, may calibrate with one test provided e_i Level 1 limits are not exceeded. Otherwise a second test is required for calibration.

- Following the necessary tests, check the status of the control charts and follow the prescribed actions.

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:

- Scheduled calibration tests should be conducted on reference oil 270 or subsequent approved reblends assigned 100% for oil 270.

- In addition to a calibration run, labs must also pass a discrimination run on reference oil 271. The discrimination run is to be run consecutively with the calibration test sample. The discrimination run is valid for not more than 360 days from date completed. The discrimination run does not calibrate the stand, but rather confirms that the discrimination oil test result can be discriminated from the calibration oil test result when run consecutively.

4. Control Charts

In Section 1, the construction of the control charts that constitute the Lubricant Test Monitoring System is outlined. For the Sequence X, Z_0=Mean Y_i of first two operationally valid tests in the stand. The constants used for the construction of the control charts for the Sequence X, 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		Stand Prediction Error	
		Severity		Severity	
Chart Level	Limit Type	Lambda	Alarm	Limit Type	Limit
Stand	Level 1	0.3	0.000	Level 1	±1.351
	Level 2		±1.800	Level 2	±1.734
				Level 3	±2.066
Industry	Level 1	0.2	±0.775	--	--
	Level 2		±0.859	--	--

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 Stand chart of Prediction Error (e_i)

  Level 3:

  – Immediately conduct one additional reference test in the stand that triggered the alarm. Do not update the control charts until the follow up reference test is completed and Excessive Influence (refer to Section 1.A.5) has been performed.

  Level 2:

  – The Level 2 limit applies in situations that have been pre-determined by the surveillance panel to have a potential impact on test results. These situations may include the introduction of new critical parts, fuel batches, reference oil reblends, or other test components. When these conditions have been met and a Level 2 alarm is triggered, immediately conduct one additional reference test in the stand that triggered the alarm.

- Exceed Stand EWMA of Standardized Test Result (Z_i)

  Level 2:

  – Immediately conduct one additional reference test in the stand that triggered the alarm. The stand that triggered the alarm is not qualified for non-reference tests until the Level 2 alarm is cleared.
  – In instances where surveillance panel has deemed that industry-wide circumstances are impacting the Level 2 alarm, the TMC may be asked to review stand calibration status in accordance with the surveillance panel's findings.

  Level 1:

  – The Level 1 limit applies to all reference tests that are control charted, even when other alarms have been triggered. Level 1 uses Z_i to determine the stand severity adjustment (SA). Calculate the stand SA as follows and confirm the calculation with the TMC:

    Chain Stretch (ln(CHST)): $SA = (-Z_i) \times (0.17856)$

The following are the steps that must be taken to determine the acceptability of the discrimination test:

After a successful calibration attempt with reference oil 270, conduct a reference test using reference oil 271 and chart the result for information purposes (do not include the result in the stand EWMA calculation)

– If 271 result is less than the lower Level 3 Ei limit (-2.066), discrimination criteria is met, that is discrimination test is passed. If not, if 271 result is within Level 3 Ei limit (-2.066 to 2.066), test is deemed normal and discrimination test is acceptable. If not compare the transformed result obtained with reference oil 270 with the 271 transformed result. If transformed chain stretch of 270 is at least 0.32362 greater than that obtained with reference oil 271, the discrimination test is acceptable. If none of the criteria are met, conduct another discrimination test using reference oil 271. Where multiple results have been conducted on reference oil 270, use the average of the results used to successfully calibrate the stand, for comparison with reference oil 271.

• Exceed Industry EWMA of Standardized Test Result (Z_i)

Level 2:

– TMC informs the surveillance panel that the limit has been exceeded. The surveillance panel then investigates and pursues resolution of the alarm.

Level 1:

– TMC informs the surveillance panel that the limit has been exceeded. The surveillance panel then investigates and pursues resolution of the alarm.

– The TMC investigates whether severity adjustments are adequately addressing the trend, investigates the possible causes, and communicates as appropriate with industry.

11. Sequence VIE LTMS Requirements

The following are the specific Sequence VIE 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 109 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
542-2	2.56	0.280
542-3	2.56	0.280
542-4	2.56	0.280
542-5	2.56	0.280
544	1.30	0.214
544-1	1.30	0.214
1010-1	1.90	0.199
1010-2	1.90	0.199

FUEL ECONOMY IMPROVEMENT at 109 Hours
Unit of Measure: Percent

Reference Oil	Mean	Standard Deviation
542-2	1.73	0.260
542-3	1.73	0.260
542-4	1.73	0.260
542-5	1.73	0.260
544	1.41	0.256
544-1	1.41	0.256
1010-1	1.82	0.327
1010-2	1.82	0.327

B. Reference Oil Assignment:

100% of the scheduled calibration tests shall be conducted on reference oils 542, 544, and 1010 or subsequent approved reblends with reference oils 542 and 1010 assigned 40% each and reference oil 544 assigned for 20% of reference attempts. If possible, the same oil should not be used for successive calibration tests in a stand.

C. Control Charts

In Section 1, the construction of the control charts that contribute to the Lubricant Test Monitoring System is outlined. For Sequence VIE, the following two statistics are used for calibration purposes at the stand/engine level for each parameter.

$$Average\ Y_i = W_i = \frac{Y_i + Y_{i-1} + Y_{i-2}}{n}$$

$$Repeatabilty\ Check = V_i = \frac{(Y_i - W_{i-1})}{R}$$

Where R = 0.919 for FEI1 and R = 0.904 for FEI2. Note, V_1 is not calculated or used and Y_1 and W_1 are equivalent.

For stand and Industry EWMA charts, Z_0=0. The calculation and calibration constants used for the construction of the control charts for the VIE, and the response necessary in the case of control chart limit alarms, are depicted below. As of March 14, 2018 stand EWMA charts using data that had industry correction factors applied were implemented for severity adjustment calculations. To initiate the stand control charts up to three previous reference tests in the stand were used.

LUBRICANT TEST MONITORING SYSTEM CONSTANTS

Chart Level	Statistic	LAMBDA	Limit
Stand/Engine	Average Yi	N/A	±2.500
	Repeatability Check	N/A	±2.80
Stand	Severity EWMA	0.6	±0.000
Industry	Severity EWMA	0.2	±0.859

D. Acceptance Criteria

1. New Test Laboratory

   a. A new test laboratory will require four operationally valid calibration tests (uninterrupted by non-reference oil tests) on multiple reference oils, in a single stand/engine combination, with at least one reference oil replicated. None of the tests need pass acceptance limits.

2. New Stand/Engine

   a. A minimum of one operationally valid calibration test, with no acceptance limits exceeded (all parameters), is required to calibrate each stand/engine.

- First operationally valid stand/engine calibration test;

  – If the Yi exceeds the stand/engine limit, then an additional calibration test is required in order to judge engine calibration. The laboratory has the option to remove the stand/engine.

  – If the Yi, does not exceed the stand/engine limit, then calculate a stand/engine Severity Adjustment (SA) for each parameter.

- Second operationally valid stand/engine calibration test;

  – If the repeatability check exceeds the limit or the average Yi exceeds the limit, then an additional calibration test is required in order to judge engine calibration. The laboratory has the option to remove the stand/engine.

  – If the repeatability check does not exceed the limit and the average Yi, does not exceed the limit, then calculate a stand/engine Severity Adjustment (SA) for each parameter.

- Third operationally valid stand/engine calibration test;

  – If the repeatability check exceeds the limit or the average Yi exceeds the limit, any additional testing on the stand/engine is not suitable for calibration purposes.

  – If the repeatability check does not exceed the limit and the average Yi, does not exceed the limit, then calculate a stand/engine Severity Adjustment (SA) for each parameter .

- Exceed Stand EWMA of Standardized Test Result (Z_i)

  – The EWMA limit applies to all reference tests that are control charted, even when other alarms have been triggered. The EWMA alarm uses Z_i to determine stand severity adjustment (SA). Calculate the stand SA as follows and confirm the calculation with the TMC:

$$\text{FEI1:} \quad SA = (-Z_i) \times (0.235)$$
$$\text{FEI2:} \quad SA = (-Z_i) \times (0.281)$$

Note that tests exceeding the Yi limit are capped at the Yi limit (±2.5) for the purposes of calculating Z_i

- Exceed EWMA Industry chart severity limit

  – TMC informs the surveillance panel that the limit has been exceeded. The surveillance panel then investigates and pursues resolution of the alarm.

3. 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.

12. Sequence VIF LTMS Requirements

The following are the specific Sequence VIF 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 109 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
1011	1.57	0.20
1011-1	1.57	0.20
543	1.78	0.34
543-1	1.78	0.34

FUEL ECONOMY IMPROVEMENT at 109 Hours
Unit of Measure: Percent

Reference Oil	Mean	Standard Deviation
1011	1.46	0.28
1011-1	1.46	0.28
543	1.99	0.27
543-1	1.99	0.27

B. Reference Oil Assignment:

100% of the scheduled calibration tests shall be conducted on reference oils 543 and 1011 or subsequent approved reblends. If possible, the same oil should not be used for successive calibration tests in a stand. Where possible, oils should be run in the order of 543 first and 1011 next. In the case of a failed reference test, either oil may be used for the subsequent test.

C. Control Charts

In Section 1, the construction of the control charts that contribute to the Lubricant Test Monitoring System is outlined. For Sequence VIF, the following two statistics are used for calibration purposes at the stand/engine level for each parameter.

$$Average\ Y_i = W_i = \frac{Y_i + Y_{i-1} + Y_{i-2}}{n}$$

$$Repeatabilty\ Check = V_i = \frac{(Y_i - W_{i-1})}{R}$$

Where R = 1.00 for FEI1 and R = 0.95 for FEI2.

The calculation and calibration constants used for the construction of the control charts for the VIF, and the response necessary in the case of control chart limit alarms, are depicted below.

LUBRICANT TEST MONITORING SYSTEM CONSTANTS

Chart Level	Statistic	LAMBDA	Limit
Stand/Engine	Average Yi	N/A	±2.000
	Repeatability Check, FEI1	N/A	+4.46 -2.80
	Repeatability Check, FEI2	N/A	±2.80
Industry	Severity EWMA	0.2	±0.859

D. Acceptance Criteria

1. New Stand/Engine

a. A minimum of two operationally valid calibration test, with no acceptance limits exceeded (all parameters), is required to calibrate each stand/engine. Severity adjustments are only to be evaluated after an acceptable calibration test.

- Second operationally valid calibration test;

- If the repeatability check does not exceed the limit and the average Yi, does not exceed the limit, then calculate a stand/engine Severity Adjustment (SA) for each parameter as follows:

FEI1: $SA = (-W_i) \times (0.27)$
FEI2: $SA = (-W_i) \times (0.27)$

- If the repeatability check exceeds the limit or the average Yi exceeds the limit, then an additional calibration test is required in order to judge engine calibration. The laboratory has the option to remove the stand/engine.

- Third operationally valid calibration test;

  - If the repeatability check does not exceed the limit and the average Yi, does not exceed the limit, then calculate a stand/engine Severity Adjustment (SA) for each parameter as follows:

$$\text{FEI1: } SA = (-W_i) \times (0.27)$$
$$\text{FEI2: } SA = (-W_i) \times (0.27)$$

  - If the repeatability check exceeds the limit or the average Yi exceeds the limit, any additional testing on the stand/engine is not suitable for calibration purposes.

- Exceed EWMA Industry chart severity limit

  - TMC informs the surveillance panel that the limit has been exceeded. The surveillance panel then investigates and pursues resolution of the alarm.

3. 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.

13. Sequence VIII LTMS Requirements

The following are the specific Sequence VIII calibration test requirements.

A. Reference Oils and Parameters

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

TOTAL BEARING WEIGHT LOSS
Unit of Measure: mg
CRITICAL PARAMETER

Reference Oil	Mean	Standard Deviation
1009-1	14.0	3.38

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

Reference Oil	Mean	Standard Deviation
1009-1	9.77	0.07

B. Acceptance Criteria

1. New Test Stand-Engines

- A minimum of two (2) operationally valid calibration tests, with no Level 1 e_i or Level 2 Z_i alarms after the second operationally valid test must be conducted in a new stand-engine on the approved reference oil. If the above criteria cannot be met then a minimum of three (3) operationally valid calibration tests, with no Level 3 e_i or level 2 Z_i alarms after the third operationally valid test must be conducted in a new stand-engine on any approved reference oils.

2. Existing Test Stand-Engines

- The stand-engine must have previously been accepted into the system by meeting the LTMS requirements
- Existing test stand-engines that have run an acceptable reference in the past 180 days may calibrate with 1 test.
- Following the necessary tests, check the status of the control charts and follow the prescribed actions.

3. Reference Oil Assignment

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

- Scheduled calibration tests should be conducted on reference oil 1009-1 and subsequent approved reblends.

4. Control Charts

In Section 1, the construction of the control charts that constitute the Lubricant Test Monitoring System is outlined. For the Sequence VIII, Z_0 =mean Y_i of the first two operationally valid tests in the stand-engine. 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. Note that control charting all parameters is required.

LUBRICANT TEST MONITORING SYSTEM CONSTANTS

		EWMA Chart		Stand-Engine Prediction Error	
		Severity		Severity and Precision	
Chart Level	Limit Type	Lambda	Alarm	Limit Type	Limit
Stand-Engine	Level 1	0.3	±0.000	Level 1	±1.515
	Level 2		±1.8000	Level 2	±1.734
				Level 3	±2.066
Industry	Level 1	0.2	±0.775	--	--
	Level 2		±0.859	--	--

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-engine from the system.

- Exceed Stand-Engine chart of Prediction Error (e_i)

Level 3:

- Immediately conduct one additional reference test in the stand-engine that triggered the alarm. Do not update the control charts until the follow up reference test is completed and Excessive Influence (refer to Section 1.A.5) has been performed.

Level 2:

- The Level 2 limit applies in situations that have been pre-determined by the surveillance panel to have a potential impact on test results. These situations may include the introduction of new critical parts, fuel batches, reference oil reblends, or other test components. When these conditions have been met and a Level 2 alarm is triggered, immediately conduct one additional reference test in the stand-engine that triggered the alarm. Evaluate the subsequent test(s) using Level 3 limit.

Level 1:

- The Level 1 limit applies to the first two tests in a new stand-engine. When a Level 1 alarm is exceeded, immediately conduct one additional test in the stand-engine that triggered the alarm. Evaluate subsequent test(s) using the Level 3 limit.

- Exceed Stand-Engine EWMA of Standardized Test Result (Z_i)

Level 2:

- Conduct one additional reference test in the stand-engine that triggered the alarm. The stand-engine that triggered the alarm is not qualified for non-reference tests until the Level 2 alarm is cleared.

- In instances where the surveillance panel has deemed that industry-wide circumstances are impacting the Level 2 alarm, the TMC may be asked to review stand-engine calibration status in accordance with the surveillance panel's findings.

Level 1 (TBWL only):

- The Level 1 limit applies to all reference tests that are control charted, even when other alarms have been triggered. Level 1 uses Zi to determine the stand-engine severity adjustment (SA). Calculate the stand-engine SA as follows and confirm the calculation with the TMC:

TBWL SA = $(-Z_i)$ *3.38

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

- Exceed Industry EWMA of Standardized Test Result (Z_i)

Level 2:

- The TMC informs the surveillance panel that the limit has been exceeded. The surveillance panel then investigates and pursues resolution of the alarm.

Level 1:

- The TMC investigates whether severity adjustments are adequately addressing the trend, investigates the possible causes, and communicates as appropriate with industry.

14. 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.

15. 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.
a. a previously calibrated stand that has undergone significant hardware, software, or control system changes.
b. 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.

16. 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

TOP GROOVE FILL
Unit of Measure: LN(TGF+1)
CRITICAL PARAMETER

Reference Oil	Mean	Standard Deviation
809-1	3.410591	0.563970
811-1	3.077855	0.362927
811-2	2.961267	0.361554

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

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

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.
c. a previously calibrated stand that has undergone significant hardware, software, or control system changes.
d. 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:	$SA = (-Z_i) \times (27.1)^1$
Top Groove Fill:	$SA = (-Z_i) \times (0.488165)^2$
Top Land Heavy Carbon:	$SA = (-Z_i) \times (0.9)^1$

[1] s based on reference oil 1004-1
[2] s based on reference oil 811-1 and 811-2 on 1Y-3998 liners

  – 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.

17. 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.

18. 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.

19. 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
Normal K Value

Reference Oil	Mean	Standard Deviation
831-3	46.02	5.90
831-4	46.02	5.90

TOP LAND CARBON
Unit of Measure: Demerits
Normal K Value

Reference Oil	Mean	Standard Deviation
831-3	21.87	7.89
831-4	21.87	7.89

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

Reference Oil	Mean	Standard Deviation
831-3	5.5089	0.7141
831-4	5.5089	0.7141

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

Reference Oil	Mean	Standard Deviation
831-3	2.8828	0.2900
831-4	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	Parameters	Limit Type	Precision	Severity	Precision	Severity	Precision	Severity
Stand	Normal K	Action	0.3	0.3	1.80	2.10	1.80	2.00
Stand	Expanded K	Action	0.3	0.3	1.80	2.10	1.80	3.00
Industry	Normal K & Expanded K	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.

20. C13 Aeration Test (COAT) LTMS Requirements

The following are the specific COAT calibration test requirements.

A. Reference Oils and Critical Performance Criteria

The prediction error monitoring and severity adjustment parameter is Percent Aeration (Averaged from 40 through 50 hours using predicted baseline density from D4052 measurements). The reference oils required for calibration are reference oils accepted by the ASTM Caterpillar Surveillance Panel. The targets for the current reference oils for each parameter are presented below.

40-50 Hr Average Aeration
Unit of Measure: Percent

Reference Oil	Mean	Standard Deviation
832	10.67	0.203
832-1	10.23	0.2774
833	11.94	0.285
833-1	11.94	0.2774

B. Acceptance Criteria

1. New stand build

- A minimum of three (3) operationally valid reference and/or matrix tests with no level 3 e_i alarms must be run on each engine-stand before calibration is considered.
- The three (3) tests must be conducted on reference oils 833, 832 and 833 in that order.
- Note that industry matrix runs may be included, as well as reference runs, at the discretion of the surveillance panel.
- Following the necessary tests, check the status of the control charts and follow the prescribed actions

2. Rebuilt or new engine with existing stand

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

- A minimum of two (2) operationally valid reference and/or matrix tests with no level 3 e_i alarms must be run on each engine-stand before calibration is considered.
- The two (2) tests must be conducted on reference oils 833 and 832 (or subsequent approved reblends) in that order.

- Following the necessary tests, check the status of the control charts and follow the prescribed actions

3. Existing Test Stand

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

   - All operationally valid calibration test results on reference oils 833 (PC11K) and 832 (PC11G) 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.

   - Note that industry matrix runs may be included, as well as reference runs, at the discretion of the surveillance panel.

4. 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:

   - Scheduled calibration tests should be conducted on reference oils 833 and 832 or subsequent approved reblends on a 2:1 ratio basis.

5. Chart Status

   In Section 1, the construction of the control charts that constitute the Lubricant Test Monitoring System is outlined. For the COAT, Z_0=Mean Y_i of first three operationally valid calibration tests. The constants used for the construction of the control charts for the COAT, and the response necessary in the case of control chart limit alarms, are depicted below.

LUBRICANT TEST MONITORING SYSTEM CONSTANTS

		EWMA Chart		Engine –Stand Prediction Error	
		Severity		Severity	
Chart Level	Limit Type	Lambda	Alarm	Limit Type	Limit
Engine - Stand	Level 1	0.3	0.000	Level 1	±1.351
	Level 2		±1.800	Level 2	±1.734
Industry	Level 1	0.2	±0.775	Level 3	±2.066
	Level 2		±0.859	--	--

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 or engine from the system.

- Exceed engine – stand Prediction Error (e_i)

  Level 3:

  – Immediately conduct one additional reference test in the engine-stand that triggered the alarm. Do not update the control charts until the follow up reference test is completed and the Excessive Influence (refer to Section 1.A.5) has been performed.

  Level 2:

  – The Level 2 limit applies in situations that have been pre-determined by the surveillance panel to have a potential impact on test results. These situations may include the introduction of new critical parts, fuel batches, reference oil reblends, or other test components. When these conditions have been met and a Level 2 alarm is triggered, immediately conduct one additional reference test in the engine-stand that triggered the alarm.

  Level 1:

  – The Level 1 limit also applies to an engine in an existing test stand that has not run an acceptable reference in the past two years. The engine can calibrate with one test if the Level 1 limits are not exceeded. Otherwise, immediately conduct another reference test in the engine-stand.

- Exceed Engine – Stand EWMA of Standardized Test Result (Z_i)

  Level 2:

  – Immediately conduct one additional reference test in the engine-stand that triggered the alarm. The engine-stand that triggered the alarm is not qualified for non-reference tests until the Level 2 alarm is cleared.

  – In instances where surveillance panel has deemed that industry-wide circumstances are impacting the Level 2 alarm, the TMC may be asked to review engine-stand calibration status in accordance with the surveillance panel's findings.

  Level 1:

  – The Level 1 limit applies to all reference tests that are control charted, even when other alarms have been triggered. Level 1 uses Z_i to determine the engine-stand severity adjustment (SA). Calculate the engine-stand SA as follows and confirm the calculation with the TMC:

    Percent Aeration Average from 40 through 50 hours: $SA = -Z_i \times (0.2774)$

- Exceed Industry EWMA of Standardized Test Result (Z_i)

Level 2:

– TMC informs the surveillance panel that the limit has been exceeded. The surveillance panel then investigates and pursues resolution of the alarm.

Level 1:

– The TMC investigates whether severity adjustments are adequately addressing the trend, investigates the possible causes, and communicates as appropriate with industry.

21. 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: LN(ACSW)

Reference Oil	Mean	Standard Deviation
831-3	3.7495	0.2302
831-4	3.7495	0.2302
835	3.9338	0.2302

AVERAGE TAPPET WEIGHT LOSS
Unit of Measure: SQRT(ATWL)

Reference Oil	Mean	Standard Deviation
831-3	9.8590	1.1755
831-4	9.8590	1.1755
835	9.7057	1.1755

B. Acceptance Criteria

1. New Test Stand

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

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 level 3 e_i or level 2 Z_i alarms must be conducted on any approved reference oil.
- Following the necessary tests, check the status of the control charts and follow the prescribed actions.

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 control charts that constitute the Lubricant Test Monitoring System is outlined. For the ISB, Z_0=mean Y_i of the first two operationally valid tests in the stand. 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. Note that control charting all parameters is required.

LUBRICANT TEST MONITORING SYSTEM CONSTANTS

		EWMA Chart		Stand Prediction Error	
Chart Level	Limit Type	Lambda	Alarm	Limit Type	Limit
Stand	Level 1	0.3	0.000	Level 2	±1.734
	Level 2		±1.800	Level 3	±2.066
Industry	Level 1	0.2	±0.775	--	--
	Level 2		±0.859	--	--

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 Stand chart of Prediction Error (e_i)

Level 3:

– Conduct one additional reference test in the stand that triggered the alarm. Do not update the control charts until the follow up reference test is completed and the Excessive Influence (refer to Section 1.A.5) has been performed.

Level 2:

– The Level 2 limit applies in situations that have been pre-determined by the surveillance panel to have a potential impact on test results. These situations may include the introduction of new critical parts, fuel batches, reference oil reblends, or other test components. When these conditions have been met and a Level 2 alarm is triggered, immediately conduct one additional reference test in the stand that triggered the alarm. Evaluate any subsequent test(s) using Level 3 e_i limits.

Exceed Stand EWMA of Standardized Test Result (Z_i)

Level 2:

– Conduct one additional reference test in the stand that triggered the alarm. The stand that triggered the alarm is not qualified for non-reference tests until the Level 2 alarm is cleared.
– In instances where surveillance panel has deemed that industry-wide circumstances are impacting the Level 2 alarm, the TMC may be asked to review stand calibration status in accordance with the surveillance panel's findings.

Level 1:

– The Level 1 limit applies to all reference tests that are control charted, even when other alarms have been triggered. Level 1 uses Z_i to determine the stand severity adjustment (SA). Calculate the stand SA as follows and confirm the calculation with the TMC:

Average Cam Shaft Wear: $SA = (-Z_i) \times (0.2032)$
Average Tappet Weight Loss: $SA = (-Z_i) \times (1.1755)$

- Exceed Industry EWMA of Standardized Test Result (Z_i)

Level 2:

- TMC informs the surveillance panel that the limit has been exceeded. The surveillance panel then investigates and pursues resolution of the alarm.

Level 1:

- The TMC investigates whether severity adjustments are adequately addressing the trend, investigates the possible causes, and communicates as appropriate with industry.

22. ISB Viscosity 108 (ISBV108) LTMS Requirements

The following are the specific ISBV108 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 Cummins 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
834	3.81	0.220

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

Reference Oil	Mean	Standard Deviation
834	4.40	0.257

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

Reference Oil	Mean	Standard Deviation
834	4.48	0.296

MRV VISCOSITY
Unit of Measure: cP
NONCRITICAL PARAMETER

Reference Oil	Mean	Standard Deviation
834	7522	373.5

B. Acceptance Criteria

1. New Test Lab

a. A New Test Lab is one that has never been in calibration before for either the ISBV108 or the ISBV156 test method.

- A minimum of two (2) operationally valid calibration tests with no Level 3 e_i or Level 2 Z_i alarms on the SOOT @ 12.0 cSt and SOOT @ 15.0 cSt parameters after the second operationally valid test must be conducted in a new Lab on any approved reference oils using the ISBV108 test method. If the above criteria cannot be met, then a minimum of three (3) operationally valid calibration tests, with no Level 3 ei or Level 2 Zi alarms after the third operationally valid test must be conducted in a new Lab on any approved reference oils.

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

- Z_0 = Mean Yi of all operationally valid tests in the initial Stand calibration for all test parameters.

2. New Test Stand within an existing Test Lab via ISBV108 or ISBV156 test method

- The test Lab must have been ASTM TMC calibrated previously and accepted into the system by meeting LTMS calibration requirements for either the ISBV108 or the ISBV156 test method.

- A minimum of 1 operationally valid calibration test result with a $|Yi| < 1.0$ is required for the Stand calibration for the SOOT @ 12.0 cSt and SOOT @ 15.0 cSt parameters. If this criterion cannot be met, then a minimum of two (2) operationally valid calibration tests, with no Level 3 ei or Level 2 Zi alarms after the second operationally valid test must be conducted on the Stand on any approved reference oils.

- Z_0 = Mean Yi of all operationally valid tests in the initial Stand calibration procedure whether it be through (1), (2) or more tests that are required to achieve initial calibration with no Level 3 e_i or Level 2 Z_i alarms on critical parameters.

- 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.

4. Control Charts

In Section 1, the construction of the control charts that constitute the Lubricant Test Monitoring System is outlined. Z_0=mean Y_i of all ISBV108 tests needed to initially calibrate the Stand. In an already existing calibrated Lab (via the ISBV108 and/or ISBV156), a new Stand requires a minimum of 1 test provided that $|Yi| < 1.0$ for the SOOT @ 12.0 cSt and SOOT @ 15.0 cSt parameters in that test. The constants used for the construction of the control charts for the ISBV108, and the responses necessary in the case of control chart limit alarms, are depicted below.

LUBRICANT TEST MONITORING SYSTEM CONSTANTS

		EWMA Chart		Shewhart Chart	Stand Prediction Error	
Chart Level	Lambda	Limit Type	Limit	New Stand in Existing Lab	Limit Type	Limit
Stand	0.3	Level 1	0	±1.0	Level 1	±1.351
		Level 2	±1.800		Level 2	±1.734
			--		Level 3	±2.066
Industry	0.2	Level 1	±0.775		--	--
		Level 2	±0.859		--	--

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 Stand Shewhart Chart Limit (Y_i) on a New Stand in Existing Lab

  Alarm (Soot @ 12cst and Soot @ 15cst parameters only):

  - Conduct one additional reference test in the Stand that triggered the alarm. Do not update the control charts until the follow up reference test is completed and the Excessive Influence analysis (refer to Section 1.A.5) has been performed.

- Exceed Stand chart of Prediction Error (e_i)

  Level 3 (critical parameters only):

  - Conduct one additional reference test in the Stand that triggered the alarm. Do not update the control charts until the follow up reference test is completed

and the Excessive Influence analysis (refer to Section 1.A.5) has been performed.

Level 2 (critical parameters only):

- The Level 2 limit applies in situations that have been pre-determined by the surveillance panel to have a potential impact on test results. These situations may include the introduction of new critical parts, fuel batches, reference oil reblends, or other test components. When these conditions have been met and a Level 2 alarm is triggered, immediately conduct one additional reference test in the stand that triggered the alarm. Evaluate any subsequent test(s) using Level 3 e_i limits.

Level 1 (critical parameters only):

- The Level 1 limit also applies to a Stand in an existing test lab that has not run an acceptable reference in the past two years. The Stand can calibrate with one test if the Level 1 limits are not exceeded. Otherwise, conduct another reference test in the Stand.

- Exceed Stand EWMA of Standardized Test Result (Z_i)

Level 2 (critical parameters only):

- Conduct one additional reference test in the Stand that triggered the alarm. The Stand that triggered the alarm is not qualified for non-reference tests until the Level 2 alarm is cleared.
- In instances where surveillance panel has deemed that industry-wide circumstances are impacting the Level 2 alarm, the TMC may be asked to review stand calibration status in accordance with the surveillance panel's findings.

Level 1 (all parameters except MRV Viscosity):

- The Level 1 limit applies to all reference tests that are control charted, even when other alarms have been triggered. Level 1 uses Z_i to determine the laboratory severity adjustment (SA). Calculate the laboratory SA as follows and confirm the calculation with the TMC:

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

Soot at 4.0 cSt Viscosity Increase:	$SA = (-Z_i) \times (0.220)$
Soot at 12.0 cSt Viscosity Increase:	$SA = (-Z_i) \times (0.257)$
Soot at 15.0 cSt Viscosity Increase:	$SA = (-Z_i) \times (0.296)$

- Confirm calculations with the TMC.

- Exceed Industry EWMA of Standardized Test Result (Z_i)

Level 2:

- TMC informs the surveillance panel that the limit has been exceeded. The surveillance panel then investigates and pursues resolution of the alarm.

Level 1:

- The TMC investigates whether severity adjustments are adequately addressing the trend, investigates the possible causes, and communicates as appropriate with industry.

23. ISB Viscosity 156 (ISBV156) LTMS Requirements

The following are the specific ISBV156 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 Cummins 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
822-2	3.07	0.271

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

Reference Oil	Mean	Standard Deviation
822-2	6.09	0.301

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

Reference Oil	Mean	Standard Deviation
822-2	6.46	0.293

MRV VISCOSITY
Unit of Measure: cP
NONCRITICAL PARAMETER

Reference Oil	Mean	Standard Deviation
822-2	14125	827.9

B. Acceptance Criteria

1. New Test Lab

b. A New Test Lab is one that has never been in calibration before for either the ISBV108 or the ISBV156 test method.

- A minimum of two (2) operationally valid calibration tests with no Level 3 e_i or Level 2 Z_i alarms on the SOOT @ 12.0 cSt and SOOT @ 15.0 cSt parameters after the second operationally valid test must be conducted in a new Lab on any approved reference oils using the ISBV156 test method. If the above criteria cannot be met, then a minimum of three (3) operationally valid calibration tests, with no Level 3 ei or Level 2 Zi alarms after the third operationally valid test must be conducted in a new Lab on any approved reference oils.

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

- Z_0 = Mean Yi of all operationally valid tests in the initial Stand calibration for all test parameters.

2. New Test Stand within an existing Test Lab via ISBV108 or ISBV156 test method

- The test Lab must have been ASTM TMC calibrated previously and accepted into the system by meeting LTMS calibration requirements for either the ISBV108 or the ISBV156 test method.

- A minimum of 1 operationally valid calibration test result with a $|Yi| < 1.0$ is required for the Stand calibration for the SOOT @ 12.0 cSt and SOOT @ 15.0 cSt parameters. If this criterion cannot be met, then a minimum of two (2) operationally valid calibration tests, with no Level 3 ei or Level 2 Zi alarms after the second operationally valid test must be conducted on the Stand on any approved reference oils.

- Z_0 = Mean Yi of all operationally valid tests in the initial Stand calibration procedure whether it be through (1), (2) or more tests that are required to achieve initial calibration with no Level 3 e_i or Level 2 Z_i alarms on critical parameters.

- 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.

4. Control Charts

In Section 1, the construction of the control charts that constitute the Lubricant Test Monitoring System is outlined. Z_0=mean Y_i of all ISBV156 tests needed to initially calibrate the Stand. In an already existing calibrated Lab (via the ISBV108 and/or ISBV156), a new Stand requires a minimum of 1 test provided that $|Yi| < 1.0$ for the SOOT @ 12.0 cSt and SOOT @ 15.0 cSt parameters in that test. The constants used for the construction of the control charts for the ISBV156, and the responses necessary in the case of control chart limit alarms, are depicted below.

LUBRICANT TEST MONITORING SYSTEM CONSTANTS

		EWMA Chart		Shewhart Chart	Stand Prediction Error	
Chart Level	Lambda	Limit Type	Limit	New Stand in Existing Lab	Limit Type	Limit
Stand	0.3	Level 1	0	±1.0	Level 1	±1.351
		Level 2	±1.800		Level 2	±1.734
			--		Level 3	±2.066
Industry	0.2	Level 1	±0.775		--	--
		Level 2	±0.859		--	--

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 Stand Shewhart Chart Limit (Y_i) on a New Stand in Existing Lab

  Alarm (Soot @ 12cst and Soot @ 15cst parameters only):

  - Conduct one additional reference test in the Stand that triggered the alarm. Do not update the control charts until the follow up reference test is completed and the Excessive Influence analysis (refer to Section 1.A.5) has been performed.

- Exceed Stand chart of Prediction Error (e_i)

  Level 3 (critical parameters only):

  - Conduct one additional reference test in the Stand that triggered the alarm. Do not update the control charts until the follow up reference test is completed

and the Excessive Influence analysis (refer to Section 1.A.5) has been performed.

Level 2 (critical parameters only):

- The Level 2 limit applies in situations that have been pre-determined by the surveillance panel to have a potential impact on test results. These situations may include the introduction of new critical parts, fuel batches, reference oil reblends, or other test components. When these conditions have been met and a Level 2 alarm is triggered, immediately conduct one additional reference test in the stand that triggered the alarm. Evaluate any subsequent test(s) using Level 3 e_i limits.

Level 1 (critical parameters only):

- The Level 1 limit also applies to a Stand in an existing test lab that has not run an acceptable reference in the past two years. The Stand can calibrate with one test if the Level 1 limits are not exceeded. Otherwise, conduct another reference test in the Stand.

- Exceed Stand EWMA of Standardized Test Result (Z_i)

  Level 2 (critical parameters only):

  – Conduct one additional reference test in the Stand that triggered the alarm. The Stand that triggered the alarm is not qualified for non-reference tests until the Level 2 alarm is cleared.

  – In instances where surveillance panel has deemed that industry-wide circumstances are impacting the Level 2 alarm, the TMC may be asked to review stand calibration status in accordance with the surveillance panel's findings.

  Level 1 (all parameters except MRV Viscosity):

  – The Level 1 limit applies to all reference tests that are control charted, even when other alarms have been triggered. Level 1 uses Z_i to determine the laboratory severity adjustment (SA). Calculate the laboratory SA as follows and confirm the calculation with the TMC:

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

Soot at 4.0 cSt Viscosity Increase:	$SA = (-Z_i) \times (0.271)$
Soot at 12.0 cSt Viscosity Increase:	$SA = (-Z_i) \times (0.301)$
Soot at 15.0 cSt Viscosity Increase:	$SA = (-Z_i) \times (0.293)$

– Confirm calculations with the TMC.

- Exceed Industry EWMA of Standardized Test Result (Z_i)

  Level 2:

- TMC informs the surveillance panel that the limit has been exceeded. The surveillance panel then investigates and pursues resolution of the alarm.

Level 1:

- The TMC investigates whether severity adjustments are adequately addressing the trend, investigates the possible causes, and communicates as appropriate with industry.

24. 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
830-3	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
830-3	2.9653	0.3274

AVERAGE SLUDGE RATING
Unit of Measure: Merit Rating
CRITICAL PARAMETER

Reference Oil	Mean	Standard Deviation
830-2	9.00	0.15
830-3	8.24	0.50

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
830-3	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.

25. 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 parameter is Relative Viscosity at 4.8% Soot, 100% DIN Shear Loss (T-8E only). Viscosity Increase at 3.8% Soot and Relative Viscosity at 4.8% Soot, 50% DIN Shear Loss are non-critical parameters (T-8 and T-8E). 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
NON-CRITICAL PARAMETER

Reference Oil	Mean	Standard Deviation
1005-3	5.01	0.56
1005-4	5.01	0.56
1005-5	5.01	0.56

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

Reference Oil	Mean	Standard Deviation
1005-3	1.76	0.08
1005-4	1.76	0.08
1005-5	1.76	0.08

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

Reference Oil	Mean	Standard Deviation
1005-3	2.00	0.09
1005-4	2.00	0.09
1005-5	2.00	0.09

B. Acceptance Criteria

1. New Test Stand

- A minimum of two (2) operationally valid calibration tests with no stand Level 3 e_i or Level 2 Z_i alarms after the second operationally valid test must be conducted on any approved reference oil.

- Following the necessary tests, check the status of the control charts and follow the prescribed actions.

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.
- One operationally valid test with no level 3 e_i or level 2 Z_i alarms must be conducted on any approved reference oil.
- Following the necessary tests, check the status of the control charts and follow the prescribed actions.
- 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. For the T8 and T-8E, Z_0=mean Y_i of the first two operationally valid tests in the stand. The constants used for the construction of the control charts for the T-8 and T-8E, and the responses necessary in the case of control chart limit alarms, are depicted below.

LUBRICANT TEST MONITORING SYSTEM CONSTANTS

		EWMA Chart		Stand Prediction Error	
Chart Level	Lambda	Limit Type	Limit	Limit Type	Limit
Stand	0.3	Level 1	0	Level 1	±1.351
		Level 2	±1.800	Level 2	±1.734
			--	Level 3	±2.066
Industry	0.2	Level 1	±0.775	--	--
		Level 2	±0.859	--	--

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 Stand chart of Prediction Error (e_i)

Level 3 (critical parameters only):

- Conduct one additional reference test in the stand that triggered the alarm. Do not update the control charts until the follow up reference test is completed and the Excessive Influence analysis (refer to Section 1.A.5) has been performed.

Level 2 (critical parameters only):

- The Level 2 limit applies in situations that have been pre-determined by the surveillance panel to have a potential impact on test results. These situations may include the introduction of new critical parts, fuel batches, reference oil reblends, or other test components. When these conditions have been met and a Level 2 alarm is triggered, immediately conduct one additional reference test in the stand that triggered the alarm. Evaluate any subsequent test(s) using Level 3 e_i limits.

Level 1 (critical parameters only):

- The Level 1 limit also applies to a stand in an existing test lab that has not run an acceptable reference in the past two years. The stand can calibrate with one test if the Level 1 limits are not exceeded. Otherwise, conduct another reference test in the stand.

- Exceed Stand EWMA of Standardized Test Result (Z_i)

  Level 2 (critical parameters only):

  - Conduct one additional reference test in the stand that triggered the alarm. The stand that triggered the alarm is not qualified for non-reference tests until the Level 2 alarm is cleared.
  - In instances where surveillance panel has deemed that industry-wide circumstances are impacting the Level 2 alarm, the TMC may be asked to review stand calibration status in accordance with the surveillance panel's findings.

  Level 1 (all parameters):

  - The Level 1 limit applies to all reference tests that are control charted, even when other alarms have been triggered. Level 1 uses Z_i to determine the stand severity adjustment (SA). Calculate the stand SA as follows and confirm the calculation with the TMC:

- Calculate stand Severity Adjustment (SA) using the current stand 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 Industry EWMA of Standardized Test Result (Z_i)

  Level 2:

  - TMC informs the surveillance panel that the limit has been exceeded. The surveillance panel then investigates and pursues resolution of the alarm.

  Level 1:

  - The TMC investigates whether severity adjustments are adequately addressing the trend, investigates the possible causes, and communicates as appropriate with industry.

26. 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	1156

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:	$SA = (-Z_i) \times (1117)$

  – 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.

27. 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.

28. T-13 LTMS Requirements

The following are the specific T-13 calibration test requirements.

A. Reference Oils and Critical Performance Criteria

The critical performance criteria are IR Oxidation Peak Height at 360 hours and percent increase in 40° kinematic viscosity from 300 to 360 hours. The reference oils required for test stand and test laboratory referencing are reference oils accepted by the ASTM T-13 Test Development Task Force. The means and standard deviations for the current reference oils for each critical performance criterion are presented below.

T-13 FTIR Peak Height Oxidation
Unit of Measure: absorbance / cm

Reference Oil	Mean	Standard Deviation
823	127.4	11.1
823-1	109.3	11.1
824	48.03	11.8

Percent Increase in Viscosity at 40°C from 300 to 360 hour
Unit of Measure: SQRT(%)

Reference Oil	Mean	Standard Deviation
823	8.610	0.929
823-1	8.139	0.929
824	3.699	0.970

B. Acceptance Criteria

1. New Test Lab

   a. The first two stands in a laboratory

   - A minimum of two (2) operationally valid calibration tests and/or matrix tests, with no Level 3 e_i alarms must be conducted in a new laboratory on any approved reference oils.

   - Note that industry matrix runs may be included, as well as reference runs, at the discretion of the surveillance panel.

   - Following the necessary tests, check the status of the control charts and follow the prescribed actions

   b. Third and subsequent stands in a laboratory

- New test stands in an existing lab, and test stands in an existing test lab that have not run an acceptable reference in the past two years, may calibrate with one test provided e_i Level 1 limits are not exceeded. Otherwise a second test is required for calibration.

- For an existing test stand in an existing lab run one test.

- Following the necessary tests, check the status of the control charts and follow the prescribed actions

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 823 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. For the T-13, Z_0=Mean Y_i of first two operationally valid tests in the laboratory. The constants used for the construction of the control charts for the T-13, 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		Laboratory Prediction Error	
		Severity		Severity	
Chart Level	Limit Type	Lambda	Alarm	Limit Type	Limit
Lab	Level 1	0.3	0.000	Level 1	±1.351
	Level 2		±1.800	Level 2	±1.734
	--	--	--	Level 3	±2.066
Industry	Level 1	0.2	±0.775	--	--
	Level 2		±0.859	--	--

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 Laboratory chart of Prediction Error (e_i)

  Level 3:

  – Immediately conduct one additional reference test in the stand that triggered the alarm. Do not update the control charts until the follow up reference test is completed and the Excessive Influence (refer to Section 1.A.5) has been performed.

  Level 2:

  – The Level 2 limit applies in situations that have been pre-determined by the surveillance panel to have a potential impact on test results. These situations may include the introduction of new critical parts, fuel batches, reference oil reblends, or other test components. When these conditions have been met and a Level 2 alarm is triggered, immediately conduct one additional reference test in the stand that triggered the alarm.

  Level 1:
  – The Level 1 limit also applies to stand in an existing test lab that has not run an acceptable reference in the past two years. The stand can calibrate with one test if the Level 1 limits are not exceeded. Otherwise, immediately conduct another reference test in the stand.

- Exceed Laboratory EWMA of Standardized Test Result (Z_i)

  Level 2:

  – Immediately conduct one additional reference test in the engine-stand that triggered the alarm. The engine-stand that triggered the alarm is not qualified for non-reference tests until the Level 2 alarm is cleared.
  – In instances where surveillance panel has deemed that industry-wide circumstances are impacting the Level 2 alarm, the TMC may be asked to review engine-stand calibration status in accordance with the surveillance panel's findings.

  Level 1:

  – The Level 1 limit applies to all reference tests that are control charted, even when other alarms have been triggered. Level 1 uses Z_i to determine the laboratory severity adjustment (SA). Calculate the laboratory SA as follows and confirm the calculation with the TMC:

    T-13 FTIR Peak Height Oxidation: $SA = (-Z_i) \times (11.1)$
    Percent Increase in Viscosity at 40°C from 300 to 360 hour: $SA = (-Z_i) \times (0.929)$

- Exceed Industry EWMA of Standardized Test Result (Z_i)

Level 2:

– TMC informs the surveillance panel that the limit has been exceeded. The surveillance panel then investigates and pursues resolution of the alarm.

Level 1:

– The TMC investigates whether severity adjustments are adequately addressing the trend, investigates the possible causes, and communicates as appropriate with industry.

29. 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
1005-5	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.

30. 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.

31. 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.

32. DD13 Scuffing Test

The following are the specific DD13 Scuffing Test calibration test requirements.

A. Reference Oils and Critical Performance Criteria

The prediction error monitoring and severity adjustment parameter is Hours to Scuff. The reference oils required for calibration are reference oils accepted by the Daimler Surveillance Panel. The targets for the current reference oils for each parameter are presented below.

Hours to Scuff
Unit of Measure: Hrs

Reference Oil	Mean	Standard Deviation
864 (OIL X)	48	26
864-1	48	26

B. Acceptance Criteria

1. New Test Lab

a. The first stand in a laboratory

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

2. Existing Lab

b. Second and subsequent stands in a laboratory

- New test stands in an existing lab, and test stands that have not run an acceptable reference in the past two years in an existing test lab, may calibrate with one test provided e_i Level 1 limits are not exceeded. Otherwise a second test is required for calibration.
- For an existing test stand in an existing lab run one test.

- Following the necessary tests, check the status of the control charts and follow the prescribed actions

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 864 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. For the DD13, Z_0=Mean Y_i of first two operationally valid tests in the laboratory. The constants used for the construction of the control charts for the DD13, 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		Laboratory Prediction Error	
		Severity		Severity	
Chart Level	Limit Type	Lambda	Alarm	Limit Type	Limit
Lab	Level 1	0.3	0.000	Level 1	±1.351
	Level 2		±1.800	Level 2	±1.734
Industry	Level 1	0.2	±0.775	Level 3	±2.066
	Level 2		±0.859	--	--

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 Laboratory chart of Prediction Error (e_i)

  Level 3:

  – Immediately conduct one additional reference test in the stand that triggered the alarm. Do not update the control charts until the follow up reference test is completed and the Excessive Influence (refer to Section 1.A.5) has been performed.

  Level 2:

  – The Level 2 limit applies in situations that have been pre-determined by the surveillance panel to have a potential impact on test results. These situations may include the introduction of new critical parts, fuel batches, reference oil reblends, or other test components. When these conditions have been met and a Level 2 alarm is triggered, immediately conduct one additional reference test in the stand that triggered the alarm.

  Level 1:
  – The Level 1 limit also applies to stand in an existing test lab that has not run an acceptable reference in the past two years. The stand can calibrate with one test if the Level 1 limits are not exceeded. Otherwise, immediately conduct another reference test in the stand.

- Exceed Engine – Stand EWMA of Standardized Test Result (Z_i)

  Level 2:

  – Immediately conduct one additional reference test in the engine-stand that triggered the alarm. The engine-stand that triggered the alarm is not qualified for non-reference tests until the Level 2 alarm is cleared.
  – In instances where surveillance panel has deemed that industry-wide circumstances are impacting the Level 2 alarm, the TMC may be asked to review engine-stand calibration status in accordance with the surveillance panel's findings.

- Exceed Industry EWMA of Standardized Test Result (Z_i)

  Level 2:

  – TMC informs the surveillance panel that the limit has been exceeded. The surveillance panel then investigates and pursues resolution of the alarm.

33. L-33-1 LTMS Requirements

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

A. Reference Oils and Critical Parameter

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

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

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

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

Reference Oil	Mean	Standard Deviation
123-2	8.51	0.35
126*	8.90	0.27
155-1	9.47	0.16
155-2	9.47	0.16

*Oil 126 approved for use on T1XX hardware only.

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 126 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.

34. 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
MNP-COATED	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	7.214	0.802	6 – 8
		152-1	6.500	1.769	4 – 9
		152-2	6.500	1.769	4 – 9
		155	8.286	0.825	7 – 9
UNCOATED	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	6.182	1.328	4 – 8
		152-1	7.583	1.832	5 – 10
		152-2	7.583	1.832	5 – 10
		155	8.714	0.611	8 – 9

RIPPLING
Unit of Measure: Merits

Hardware	Pinion Batch	Reference Oil	Mean	Standard Dev.	Acceptance Band
MNP-COATED	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	7.429	1.284	6 - 9
		152-1	8.792	0.833	8 - 10
		152-2	8.792	0.833	8 - 10
		155	8.786	0.699	8 - 10
UNCOATED	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	8.364	0.809	7 - 9
		152-1	8.917	0.669	7 - 10
		152-2	8.917	0.669	8 - 10
		155	8.714	0.726	8 - 10

PITTING/SPALLING
Unit of Measure: Merits

Hardware	Pinion Batch	Reference Oil	Mean	Standard Dev.	Acceptance Band
MNP-COATED	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	9.364	1.302	7 - 10
		152-1	8.533	1.720	6 - 10
		152-2	8.533	1.720	6 - 10
		155	9.893	0.027	9.8 – 9.9
UNCOATED	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	4.364	3.491	0 - 10
		152-1	8.883	1.872	6 - 10
		152-2	8.883	1.872	6 - 10
		155	9.514	1.038	8 - 10

WEAR
Unit of Measure: Merits

Hardware	Pinion Batch	Reference Oil	Mean	Standard Dev.	Acceptance Band
MNP-COATED	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	6.357	0.497	6 - 7
		152-1	6.208	0.833	5 - 7
		152-2	6.208	0.833	5 - 7
		155	6.929	0.267	6 - 7
UNCOATED	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	5.545	0.820	5 - 7
		152-1	6.500	0.522	6 - 7
		152-2	6.500	0.522	6 - 7
		155	6.714	0.469	6 - 7

SCORING
Uncoated & MNP-coated 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 Uncoated or MNP-coated 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 Uncoated and MNP-coated 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 Uncoated and MNP-coated hardware test results are charted separately.

- Alternate MNP-coated and uncoated 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
MNP-Coated	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%
Uncoated	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 severity
  - Calculate test stand Severity Adjustment (SA) for each parameter that exceeds action limit, using the current test stand EWMA (Z_i) as follows:

    Uncoated 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: $SA = (-Z_i) \times (0.713)$

    MNP-coated 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.

35. L-37-1 LTMS Requirements

The following are the specific L-37-1 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/L-37-1 Surveillance Panel. The means and standard deviations for the current reference oils for each critical parameter are presented below.

RIDGING
Unit of Measure: Merits

Pinion Batch	Hardware	Reference Oil	Mean	Standard Dev.	Acceptance Bands
Gleason 04-2014, 06-2018, 2019/20	UNCOATED	134/134-1	4.1	0.9	-
		152-2	9.0	0.8	-
		155-1/155-2	9.5	0.5	-
Gleason 04-2014	MNP-COATED	134/134-1	6.1	2.4	-
		152-2	9.7	0.5	-
		155-1/155-2	9.3	1.0	-
Gleason 04-2021		134/134-1	-	-	4 - 6
		152-2	-	-	8 – 10
		155-1/155-2	-	-	8 – 10

RIPPLING
Unit of Measure: Merits

Pinion Batch	Hardware	Reference Oil	Mean	Standard Dev.	Acceptance Bands
Gleason 04-2014, 06-2018, 2019/20	UNCOATED	134/134-1	7.4	1.4	-
		152-2	8.3	1.2	-
		155-1/155-2	8.6	1.1	-
Gleason 04-2014	MNP-COATED	134/134-1	7.4	1.6	-
		152-2	9.3	0.5	-
		155-1/155-2	8.7	0.7	-
Gleason 04-2021		134/134-1	-	-	5 - 8
		152-2	-	-	7 – 9
		155-1/155-2	-	-	7 – 9

PITTING/SPALLING
Unit of Measure: Merits

Pinion Batch	Hardware	Reference Oil	Mean	Standard Dev.	Acceptance Bands
Gleason 04-2014, 06-2018, 2019/20	UNCOATED	134/134-1	7.9	2.0	-
		152-2	9.9	0.1	-
		155-1/155-2	9.9	0.0	-
Gleason 04-2014	MNP-COATED	134/134-1	9.9	0.1	-
		152-2	9.7	0.6	-
		155-1/155-2	9.9	0.0	-
Gleason 04-2021		134/134-1	-	-	9.8 - 9.9
		152-2	-	-	9.9 – 10.0
		155-1/155-2	-	-	9.8 – 10.0

WEAR
Unit of Measure: Merits

Pinion Batch	Hardware	Reference Oil	Mean	Standard Dev.	Acceptance Bands
Gleason 04-2014, 06-2018, 2019/20	UNCOATED	134/134-1	5.3	0.9	-
		152-2	7.6	0.7	-
		155-1/155-2	7.5	0.7	-
Gleason 04-2014	MNP-COATED	134/134-1	6.8	0.9	-
		152-2	8.2	0.7	-
		155-1/155-2	7.9	0.8	-
Gleason 04-2021		134/134-1	-	-	6 - 7
		152-2	-	-	7 – 8
		155-1/155-2	-	-	7 – 8

SCORING
Uncoated & MNP-coated 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

uncoated or MNP-coated 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 uncoated and MNP-coated 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 uncoated and MNP-coated hardware test results are charted separately.

   - Alternate MNP-coated and uncoated 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 evenly distributed among oils 134, 152-2, and 155-1 or their 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-37-1, 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 severity

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

  Uncoated Test Hardware:

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

  MNP-coated Test Hardware:

Ridging:	SA = $(-Z_i)$ x (n/a)
Rippling:	SA = $(-Z_i)$ x (n/a)
Pitting/Spalling:	SA = $(-Z_i)$ x (n/a)
Wear:	SA = $(-Z_i)$ x (n/a)

Confirm calculations with the TMC.

  – SA calculations are for information purposes only and are not to be used to adjust reported test results.

- Exceed Shewhart test stand chart action limit for severity

  – Conduct an additional calibration test.

- Exceed GL-5 minimum pass limits for all critical parameters, both MNP-coated and uncoated test hardware, reference oil 134 (and reblends) 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 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 the potential problem.

36. 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

COAST SIDE PINION SCORING
Unit of Measure: % Scoring
Gear Batch P8AD078X

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

COAST SIDE PINION SCORING
Unit of Measure: % Scoring
Gear Batch P8AD132 (Pinion ID’s C1L446, C1L637)

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

COAST SIDE PINION SCORING
Unit of Measure: % Scoring
Gear Batch P2DA01

Reference Oil	Mean	Standard Deviation
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, 119 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, 119 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) or see the test procedure for alternate single test calibration requirements. Every 6 months or fourth calibration sequence, also assign one discrimination oil 112, 113 or subsequent reblends.
P8AD078X	Assign three 116 or 117 oils (or subsequent reblend) or see the test procedure for alternate single test calibration requirements. Every 6 months or fourth calibration sequence, also assign one discrimination oil 112, 113, 119 or subsequent reblends.
P8AD132	Assign three 116 or 117 oils (or subsequent reblend) or see the test procedure for alternate single test calibration requirements. Every 6 months or fourth calibration sequence, also assign one discrimination oil 112, 113, 119 or subsequent reblends.
P2DA01	Assign three 117 oils (or subsequent reblend) or see the test procedure for alternate single test calibration requirements. Every 6 months or fourth calibration sequence, also assign one discrimination oil 119 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.

37. 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: VISI
CRITICAL PARAMETER

Reference Oil	Mean	Standard Deviation
131-3	81.451	7.659
131-4	75.944	7.659
145	70.225	5.099
148-1	36.966	7.659
151-2	37.070	2.717
155-2	23.000	2.832

PENTANE INSOLUBLES
Unit of Measure: PEN
CRITICAL PARAMETER

Reference Oil	Mean	Standard Deviation
131-3	2.293	0.413
131-4	2.560	0.413
145	1.198	0.249
148-1	0.387	0.413
151-2	2.064	0.380
155-2	1.509	0.434

AVERAGE CARBON/VARNISH
Unit of Measure: ACV
CRITICAL PARAMETER

Reference Oil	Mean	Standard Deviation
131-3	1.111	0.511
131-4	1.053	0.511
145	6.329	0.747
148-1	8.306	0.511
151-2	8.801	0.517
155-2	8.760	0.708

AVERAGE SLUDGE
Unit of Measure: ASL
CRITICAL PARAMETER

Reference Oil	Mean	Standard Deviation
131-3	9.411	0.106
131-4	9.483	0.106
145	8.575	0.648
148-1	9.532	0.106
151-2	9.382	0.106
155-2	9.426	0.101

TOLUENE INSOLUBLES
Unit of Measure: TOL
NONCRITICAL PARAMETER

Reference Oil	Mean	Standard Deviation
131-3	0.554	0.249
131-4	0.923	0.249
145	1.217	0.409
148-1	0.257	0.249
151-2	1.329	0.394
155-2	1.109	0.530

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 scheduled calibration tests should be conducted on reference oils 145 and 155-1, or subsequent approved reblends, on a 50/50 basis.

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:	$SA = (-Z_i) \times (7.659)$
Pentane Insolubles:	$SA = (-Z_i) \times (0.413)$
Toluene Insolubles:	$SA = (-Z_i) \times (0.249)$
Average Carbon/Varnish:	$SA = (-Z_i) \times (0.511)$
Average Sludge:	$SA = (-Z_i) \times (0.106)$

  - 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.

38. 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.

39. 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
170	Nitrile	-70.68	3.007
171	Polyacrylate	25.090	11.415
171	Fluoroelastomer	-47.949	5.947

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
170	Nitrile	1.500	0.718
171	Polyacrylate	0.223	1.858
171	Fluoroelastomer	0.987	1.664

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
170	Nitrile	2.325	0.341
171	Polyacrylate	-0.088	1.096
171	Fluoroelastomer	2.167	1.201

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, 169 or 171 (or subsequent reblends) for every calibration sequence.
FL	Assign reference oils 160, 161, 169 or 171 (or subsequent reblends) for every calibration sequence.
NI	Assign reference oils 161, 162, 168, 169 or 170 (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 Shewhart 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

40. D5133 (GI) TMC Calibration Requirements

The following are the specific D5133 (GI) TMC calibration test requirements.

Objective of TMC monitoring of D5133 (GI) test stands: The surveillance panel's intent is that each participating GI instrument head (viscometer drive module) and test cell (rotor and stator) combination must demonstrate accurate D5133 test performance on blind reference oils of known and varied GI severity performances at least once every 180 days, and demonstrate a passing result on a low-gelling (discrimination) reference oil every other calibration run (or, at least once every 360 days). The following requirements are intended to meet these objectives.

A. Reference Oils and Critical Parameters

1. The critical pass/fail parameter is Gelation Index (a unitless, derived value that measures the gelling tendency characteristics of a tested fluid). The reference oil performance targets and acceptance criteria required for calibration with the TMC are listed in Table 1 and have been approved by the ASTM D02.B0.07 Gelation Index Surveillance Panel.

2. Per the D5133 test method, a GI result less than 6.0 shall be reported as '<6.0', and GI result of 6.0 or greater shall be reported as a numeric value to one decimal.

Table 1
D5133 Reference Oil Targets and Acceptance Bands

						Acceptance Bands[1]	
						95%	
Test	**Oil Code**	**Parameter**	**n**	**Mean**	**sR**	**Lower**	**Upper**
GI by D5133	1009	Gelation Index	16	7.3	0.68	6.0	8.6
	62	Gelation Index	35	17.0	3.90	9.4	24.6
	GIA17	Gelation Index	18	19.0	1.87	15.4	22.7
	GIC18	Gelation Index	13	10.3	1.21	7.9	12.7
	58[2]	Gelation Index	17	<6.0	N/A	<6.0	7.2

[1] 95% Acceptance Bands = Mean +/- (1.960 x sR)
[2] Discrimination Oil

B. Test Stand Defined

1. A GI test stand is defined as a single Scanning Brookfield head (also referred to in the test method as a 'Viscometer Drive Module'), and a single rotor and stator (test cell) combination and in conformance with ASTM Test Method D5133. The test sample and test cell may be cooled by liquid bath, air or thermoelectrically. The test cell may be cooled in a common cooling bath with other test cells, or by temperature controlled blocks with one or more test cells. Each stand (head and test cell combination) is to be identified by a unique manufacturers head serial number.
2. Testing labs are permitted to limit participation to any number of test stands on a multi-head instrument (or controller) with this notification that any test stands that are not

specifically TMC calibrated under the specifications in this document cannot be used as, or implied to be, TMC calibrated test stands, heads or test cells.

C. Acceptance Criteria

1. New Laboratory/Test Stand(s)

a. All new test stands must first demonstrate acceptable discrimination performance by meeting the acceptance criteria on three ***consecutive*** blind test stand calibration runs using a TMC severe (high GI) performing GI reference oil, a TMC borderline-low GI performing reference oil, and a discrimination (low to non-gelling) GI reference oil with no significant instrument settings or changes between the runs. See Section C.2.h for a list of test stand changes considered to be operationally significant.

1. Operational conformance as well as statistical evaluation of the reported test results will be reviewed to make validity determinations. Test stands that successfully pass the initial three-test calibration/discrimination requirement are considered to be TMC calibrated until the test stand calibration expires.

2. A test stand that fails on either operational conformance or the statistical acceptance criteria will need to have the three-test runs repeated until a passing blind three-test sequence is achieved on the individual test stand.

3. The passing consecutive three-test calibration/discrimination runs on a stand must occur within a period of 21 calendar days, as determined by date completed. Intervals of more than 21 days between three required consecutive stand calibration/discrimination runs, as determined by date completed, will operationally disqualify the test stand calibration attempt.

4. The run order of the three initial required tests can be in any order, but must be consecutive, back-to-back runs.

5. All three tests of a new test stand calibration sequence must be reported before any of the test results will be evaluated for validity by the TMC.

b. TMC calibrated status of a test stand is valid for not more than 180 days from date completed of most recent of the two valid *calibration* runs (that is, the end of the test's cooling cycle needed to generate the second GI calibration test value). The date completed of the discrimination run will not be used in calculating calibration periods.

c. To renew the calibration at the end of the calibration period, see Section C.2 for Existing Laboratory/Test Stand(s).

2. Existing Laboratory Test Stand(s)

a. To maintain calibrated status, all participating test stands must demonstrate a single passing blind calibration performance at least once every 180 days. An

existing TMC calibrated test stand, or one where the TMC calibrated status has expired for not more than 90 days, can renew its TMC calibrated status by demonstrating a successful blind calibration on at least one TMC blind calibration run on a current or recently calibrated test stand. This test must pass on both operational and statistical criteria.

b. For single-test blind calibrations, blind calibration samples will be assigned in approximate equal frequency from among the current surveillance panel approved reference oils.

c. To maintain calibrated status of the test stand, a successful passing discrimination run must also be run and reported at least every 360 days, and coincident with a blind calibration run, per Section C.5.

d. TMC calibrated status of an existing test stand is valid for no more than 180 days from date completed of a valid TMC calibration (that is, the end of the test's cooling cycle needed to generate the GI calibration test value).

e. Test stands that exceed the time periods specified in either Sections C.2.a or C.2.c for calibration or discrimination runs are considered to be out of calibration for TMC monitoring purposes.

f. A test stand that has been out of TMC calibration for more than 90 days past the prior TMC test stand calibration expiration date will require a New Test Stand calibration as specified in Section C.1.

g. A single-test stand calibration must pass the TMC calibration within two operationally valid calibration attempts, and within 14 days of each other. If a stand cannot produce a calibration test that falls into the acceptance bands for the assigned oil within two operationally valid runs, and within 14 days from the first failing attempt, renewing calibration on that stand will require a New Test Stand calibration as specified in Sections C.1.

h. Any of the following significant changes voids any current TMC calibrated status and will require a New Test Stand calibration as specified in Sections C.1. The lab will add test comment to report reason for calibration.

- Replacement or exchange of a head, rotor or stator in a test stand.
- Replacement of a test cell previously matched and calibrated with a head.
- Repair of a head or test cell.

i. The following changes would void the current TMC calibration status of a test stand and require a new single calibration as required in section C.2. The lab will add test comment to report reason for calibration.

- Moving a test stand (previously matched and calibrated head and test cell) to a new bath, cooling block or controller.

j. The following changes would require a calibration run of one test stand on the controller system. The lab will add test comment to report reason for calibration.

- Repair of a central controller
- Replacement of a cooling bath thermocouple

In the event of a failing calibration run, the lab shall verify the change was not the reason for the failure by running a calibration run on another test stand on the same controller system. The failing test stand will follow the calibration requirement listed in section C.2.

3. Tracking and Reporting Test Stand Runs
   a. A stand's calibration status shall be tracked by the TMC through reported Instrument ID and Head Run Numbers. Instrument ID and Head Run Number are separate fields on the approved data dictionary. An example is:
      Instrument ID: C123456(C20)
      Head Run Number: 123456 (C10)

   b. Instrument ID shall be the serial number of the head that produced the test result being reported, and represents the monitored test stand. Repaired or overhauled heads will be reset in the test monitoring system per Section C.6.b.

   c. Head Run Number shall be a consecutive integer count of test starts on a head. Head Run Number is increased incrementally by one (1) for each new test start on a head, regardless of whether or not the test runs to completion, or whether or not the run is a TMC calibration attempt. Head Run Number will be reset to 1 for new or newly repaired heads.

4. Blind Calibration Test Evaluation:

   a. The calibration status of a test stand will be based on a review of reported operational parameters for compliance with the test method, followed by a statistical evaluation of the critical parameter test result against the acceptance ranges in Section A (commonly referred to as a Shewhart severity evaluation). Unless otherwise noted, the acceptance bands in Table 1 are based on a 95% confidence treatment of round robin test results with data exclusions as approved by the surveillance panel.

   b. Unless otherwise addressed by the panel, any operationally valid GI test result reported as '<6.0' for any non-discrimination reference oil cannot be statistically interpreted. Such reported test results will be given a validity that indicates the result is operationally valid but not statistically interpretable, and therefore not chartable. (Validity OC, Chart N)

5. Discrimination Oil Test Criteria:

   a. In order to demonstrate that the test stand can discriminate a borderline non-gelling oil from the reference oils that have measurable gelling characteristics, a low-to-non-gelling discrimination oil (TMC oil 58 or an approved replacement) shall be requested and assigned on every calibrated test stand initially (per C.1.a) and at least once every 360 days, and run consecutively

with a blind calibration run,. Operational conformance will be evaluated, as will the GI test result per Table 1. However, the discrimination test results will not be otherwise statistically evaluated (non-chartable). A GI result less than 6.0 shall be reported as '<6.0', and GI result of 6.0 or greater shall be reported as a numeric value to one decimal. TMC pass/fail evaluation of the discrimination run will be based on the approved upper acceptance limit for the discrimination oil (see Table 1). A special discrimination run validity and comment will be applied, but the discrimination test result will not be otherwise statistically interpreted.

b. A test stand must pass the acceptance criteria in Table 1 for the discrimination oil within two attempts. Failure of the first attempt on a discrimination run, while passing on the concurrent calibration run on the same test stand, will place the calibration status of the affected test stand as pending while a discrimination oil rerun is conducted. The discrimination test rerun must be completed within 14 days from the prior failing run. Passing a second consecutive discrimination run (following a failed discrimination attempt) will reinstate the calibrated status of the test stand until the test stand calibration expiration date (specified on the calibration test confirmation report). Two consecutive runs that fail to meet the acceptance criteria for the discrimination oil will void the current calibrated status of the test stand and require a full new stand calibration sequence as defined in section C.1. Shakedown runs will be permitted to troubleshoot stand performance before proceeding with the three-test calibration sequence.

c. Failure of a lab to perform and report a discrimination run to the TMC in the time period referenced in section C.2.a and C.2.c voids the current calibrated status of the test stands and require a new stand calibration sequence as specified under section C.1.

d. It is the referencing lab's responsibility to track when discrimination runs are due, the TMC will not send reminders on this.

6. Replacement or Repair of Heads:

a. Repaired or refurbished heads, and/or repaired or replaced rotors or stators will be considered as new test stands and must be (re)introduced with a successful new test stand calibration sequence, as specified in section C.1.

b. Repaired or refurbished heads, or replaced test cells, will add a suffix to the Head ID starting with '-R1' and increasing numerically ('-R2', '-R3'…) following each successive repair. Head Run Number will be reset to 1 for new or newly repaired heads or replaced test cells, reflecting a new test stand and run count series for each new or newly repaired Head ID.

7. Removal of Test Stands from the System

a. The laboratory must notify the TMC when removing a stand from the system. No reference oil data shall be removed from the TMC's data base of prior TMC calibrations or calibration attempts. Return of the stand to the system will be evaluated as a new test stand per section C.1.

8. Introduction of New or Re-Blended Reference Oils
    a. Introduction of new or replacement reference oils will be conducted at the discretion of the surveillance panel. Participating laboratories may be asked to donate tests on the new oil(s) to establish baseline performance in the D5133 (GI) test. The number of tests requested will be sufficient to rigorously evaluate the oil's performance (typically a minimum of 15 tests total among all the participating labs). Preliminary statistical performance targets and acceptance criteria will be established by the surveillance panel, and those values will be re-assessed by the panel as the TMC collects additional calibration data.

9. Internal Calibration of Test Stand
    a. In addition to the TMC blind calibrations, Test Method D5133 specifies a separate calibration check for each test cell. To differentiate this requirement from the TMC calibrations, this is to be referred to in the data dictionary as an 'internal calibration'. The internal calibration is to be successfully performed as specified in the test method. The date of the last internal calibration is to be reported to the TMC with the TMC calibration run results for the test stand being reported. As part of the operational review, the TMC will confirm that the date completed of the most recent internal calibration (DTINTCAL) is prior to, and within the time specified in the test method, from date completed of the TMC calibration (DTCOMP) for each test stand. Test stands found to have delinquent test cell internal calibrations from the test method specification will be evaluated as operationally invalid.

10. Transitioning current registered instruments from an instrument based calibration monitoring system to a head-test cell based monitoring system:

    a. From the first day of implementing the head-test cell based test stand system, ALL current head calibrations will expire within 180 days of implementation. Labs with existing calibrated *baths* will have up to 180 days to newly recalibrate all *heads* with current calibrations as newly defined *test stands* by completing a single-test calibration followed consecutively by a discrimination oil run on each head/test cell (test stand), under the specifications in this document.

    b. Any heads with current calibrations expiring prior to 180 days from the implementation of this document will need to be recalibrated as test stands by the head calibration expiration date shown on the most recent TMC Test Confirmation Report (TCR) for each currently calibrated head. This will require completing a single-test calibration followed consecutively by a discrimination oil run on each head/test cell (test stand), under the specifications in this document. Head calibrations will not be extended beyond current expiration dates as a result of this transition.

    c. . Statistics will be reset for monitoring test stands by newly registered head serial numbers as the Instrument ID.

41. D5800 Volatility by Noack Test LTMS Requirements

The following are the specific D5800 Volatility by Noack Test calibration requirements.

A. Reference Oils and Critical Parameters

The critical parameter is Sample Evaporation Loss, Mass % (evaluated in natural log transformed units). The reference oils required for test stand and test laboratory calibration are reference oils accepted by the D02.B0.07 Volatility Surveillance Panel. The means and standard deviations for the current reference oils for the critical parameter are presented below.

SAMPLE EVAPORATION LOSS
Unit of Measure: LN(mass % evaporation loss)
CRITICAL PARAMETER

Reference Oil	Mean	Standard Deviation*
VOLC12	2.6523	0.0465
VOLD12	2.5264	0.0465
VOLE12	2.8175	0.0465

*Values utilized for standard deviation to be periodically reevaluated by the D02.B0.07 Volatility Surveillance Panel

B. Acceptance Criteria

1. New Test Instrument (Test Instrument that has never previously calibrated)

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

2. Existing Test Instrument

   - Instrument has previously been accepted into the system by meeting the requirements defined in this section.

3. Transitioning Instruments To EWMA Monitoring Using Transformed Units

- On the approved effective date of the transition to evaluating tests using natural log transformed test results, February 7, 2020, the TMC will issue new TCR's for all instruments currently calibrated on that date with re-calculated severity adjustments (SA's) in natural log transformed units. On the effective date and forward, all candidate test results for final sample % mass volatized will be calculated using the new SA's based on transformed test results. Calibration status will not be revoked or granted at the time of transition, only the SA's for each rig will be recalculated. Changes in calibration status will be issued with a respective rig's next calibration interval.

4. Calibration Test Requirements and Reference Oil Assignments

After test instruments have been accepted into the system, continuing calibration requires a reference oil assignment be obtained from TMC, and a calibration test performed, when either of the following occur:

- 30 days have passed since the last successful ("in control") calibration test, OR
- the instrument has been retrofitted with a new thermocouple or new pump, or has received updated firmware.

100% of the scheduled calibration tests should be conducted on reference oils VOLC12, VOLD12 and VOLE12 or subsequent approved reblends. All operationally valid calibration tests must be charted to determine if the test instrument is currently "in control" as defined by the control charts defined in B.6.

5. Mandatory Daily QC Check Sample and Data Submission

To maintain calibrated status and comply with the daily QC check requirement defined in the current revision of ASTM D5800, all TMC-monitored instruments must use a surveillance panel-approved daily quality control check fluid. The results from *all* daily QC checks (passes and fails, whether operationally valid or invalid) since the *last operationally-valid calibration attempt* must be included in the flat file submission (report form) for each calibration run. The data required for each daily QC check shall include unique cup and lid identifiers, among other mandatory data as defined on the TMC-maintained template. Daily QC sample data is not used to determine calibration status of an instrument but it may be used on an ad-hoc basis as an indicator of the ongoing effectiveness of the D5800 LTMS system.

The current approved daily QC check fluid ID's, performance targets, and pass/fail limits are documented below. These pass/fail limits may be periodically re-evaluated by the ASTM D02.B.07 Volatility Surveillance Panel. Conversion of the QC check fluid test results to natural log is unnecessary. The QC fluid test results can be directly compared to the acceptance limits below for evaluating the acceptability of the QC test results:

					95% Acceptance Limits*	
Oil Code	**Parameter**	**N**	**Mean**	**sR**	**Lower**	**Upper**
VOLD14	Mass % evaporation loss	33	12.99	0.62	11.8	14.2
VOLD18	Mass % evaporation loss	47	12.06	0.46	11.2	13.0

*95% Acceptance Limits = Mean +/- (1.96 sR)

6. Control Charts

In Section 1, the construction of the control charts that constitute the Lubricant Test Monitoring System is outlined. For the D5800, Z_0=Mean Y_i of first two operationally valid tests for the instrument. The constants used for the construction of the control charts for the D5800 Volatility by Noack Test, and the response necessary in the case of control chart limit alarms, are depicted below.

LUBRICANT TEST MONITORING SYSTEM CONSTANTS

		EWMA Chart		Instrument Prediction Error	
Chart Level	Limit Type	Lambda*	Alarm*	Limit Type	Limit*
Instrument	Level 1	0.3	0.000	Level 2	±1.734
	Level 2		±1.800	Level 3	±2.066
Industry	Level 1	0.2	±0.775	--	--
	Level 2		±0.859	--	--

*Values for Lambda and alarm limits to be periodically reevaluated by the D02.B.07 Volatility Surveillance Panel

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 instrument from the system.

- Exceed Instrument chart of Prediction Error (e_i)

  Level 3:

  - Immediately conduct one additional reference test on the instrument that triggered the alarm. Do not update the control charts until the follow up reference test is completed and the Excessive Influence analysis (refer to Section 1.A.5) has been performed.

Level 2:

- The Level 2 limit applies in situations that have been pre-determined by the surveillance panel to have a potential impact on test results. These situations may include the introduction of new critical parts, reference oil reblends, or other test components. When these conditions have been met and a Level 2 alarm is triggered, immediately conduct one additional reference test in the instrument that triggered the alarm.

Level 1:

- The Level 1 limit does not apply for the D5800.

- Exceed Instrument EWMA of Standardized Test Result (Z_i)

Level 2:

- Immediately conduct one additional reference test in the instrument that triggered the alarm. The instrument that triggered the alarm is not qualified for non-reference tests until the Level 2 alarm is cleared.

- In instances where surveillance panel has deemed that industry-wide circumstances are impacting the Level 2 alarm, the TMC may be asked to review instrument calibration status in accordance with the surveillance panel's findings.

Level 1:

- Calculate the instrument SA as follows and confirm the calculation with the TMC:

  Sample Evaporation Loss: SA = ($-Z_i$) x Standard Deviation

  Standard Deviation (D5800) = 0.0465*

  *Value used for standard deviation to be periodically reevaluated by the D02.B0.07 Volatility Surveillance Panel

- SA's are not applied to TMC calibration test results
- SA's are instrument dependent and are to be applied to candidate test results over the instrument's active calibration period. SA's are to be applied to natural log transformed test results (LN(% mass volatized)) before conversion back to original units for the final, SA corrected, test result.
- If using translation factors, the translations factor is to be applied to the final, SA adjusted test result after conversion back to original units.
- At the expiration of the LTMS calibration period for an instrument, a new calibration is required for that instrument per Section B.4 of the D5800 LTMS specification. For acceptable (passing) calibration results, an updated SA will be calculated for the renewed calibration period on that instrument.

- Exceed Industry EWMA of Standardized Test Result (Z_i)

  Level 2:

  - TMC informs the surveillance panel that the limit has been exceeded. The surveillance panel then investigates and pursues resolution of the alarm.

  Level 1:

  - The TMC investigates whether severity adjustments are adequately addressing the trend, investigates the possible causes, and communicates as appropriate with industry.

42. D6082 High Temperature Foam Test LTMS Requirements

The following are the specific D6082 High Temperature Foam Test calibration requirements.

A. Reference Oils and Critical Parameters

The critical pass/fail parameters are Foam Tendency (immediately before air disconnect) Static Foam, ml, and Foam Stability (one-minute after air disconnect) Static Foam, ml. The reference oils, performance targets and acceptance criteria required for the test stand calibration with the TMC are listed in Table 1 and have been approved by the ASTM D02.B0.07 High Temperature Foam Surveillance Panel. Note that 'Option A' in the test method, specifically requiring the sample to be blended prior to testing, is mandatory and not an 'option' for TMC calibration or discrimination tests.

Table 1
D6082 (HT Foam) Reference Oil Targets and Acceptance Bands Effective 20080807

						Acceptance Bands*	
						95%	
Test	**Oil Code**	**Parameter**	**n**	**Mean**	**sR**	**Lower**	**Upper**
High Temp.	FOAMB18	Foam Tendency, ml	18	54	9	36	72
Foam	FOAMB18	Foam Stability, ml	18	0	0	0	0
By	1007	Foam Tendency, ml	28	66	19	29	103
D6082	1007	Foam Stability, ml	28	0	0	0	0
	66**	Foam Tendency, ml	--	---	---	>100	---
	66**	Foam Stability, ml		---	---	0	0

*95% Acceptance Bands = Mean +/- (1.960 x sR)
**Oil 66 is a severe performing foam tendency discrimination reference oil

B. Test Stand Defined

A test stand is defined as a bath (using heated air or oil medium) that is set up and approved for D6082 testing regardless of the number of individual cylinder openings. The bath (stand) may have multiple cylinder openings for testing multiple samples simultaneously or concurrently.

C. Acceptance Criteria

1. New Laboratory/Test Stand(s)

   a. The TMC calibration system calibrates individual test stands (individual temperature baths regardless of the number of cylinder openings) at individual laboratories. There are no special requirements to bring a LAB into TMC calibrated status, there are only requirements to bring individual test stands into TMC calibrated status, as follows:

b. A minimum of two (2) operationally valid tests (one calibration and one discrimination), both which meet the acceptance criteria for the oils assigned, are required to calibrate a stand for the first time. These must be concurrent runs on the same test stand.

c. Option A (requiring the test sample to be blended as specified in the test method) is mandatory for TMC calibration runs.

d. Passing a concurrent TMC calibration and discrimination places the new test stand in TMC calibrated status. Both tests must pass on operational and statistical criteria.

e. TMC calibrated status of a test stand is valid for no more than 90 days from date completed of a valid TMC calibration (that is, the day the sample is evaluated for static foam levels). To renew the calibration at the end of the calibration period, see Item 2 for Existing Laboratory/Test Stand(s).

2. Existing Laboratory/Test Stand(s)

a. An existing TMC calibrated test stand, or one where the TMC calibrated status had expired within the past 90 days, can renew its TMC calibrated status by demonstrating a successful calibration on another single TMC blind calibration audit. The test must pass on both operational and statistical criteria.

b. In addition to a calibration run, labs must also pass a discrimination run on the approved discrimination oil. The discrimination run is to be run concurrently with the calibration test sample. The discrimination run is valid for not more than 180 days from date completed. The discrimination run does not calibrate the instrument, but rather confirms that the discrimination oil test result can be discriminated from the calibration oil test result when run concurrently. Because the discrimination is due only once every 180 days, and concurrent with a TMC calibration, a discrimination run is due every other 90-day calibration cycle. For labs with multiple test stands, only one discrimination run is due every 180 days, but the discrimination runs must be rotated equally among the test stands. A failing discrimination run voids the concurrent calibration run and both runs must be repeated per Section 2 of this document.

c. Option A (requiring the sample to be blended as specified in the test method) is mandatory for TMC calibration and discrimination runs.

d. TMC calibrated status of an existing test stand is valid for no more than 90 days from date completed of a valid TMC calibration (that is, the day the sample is evaluated for static foam levels). Test stands that exceed these time/run specifications are considered to be out of calibration for TMC monitoring purposes.

e. A stand that has been out of TMC calibration for more than 90 days from the prior TMC calibration expiration date will require New Test Stand calibration as listed in C.1.b through C.1.e. of this document.

f. A stand must pass the TMC calibration within two operationally valid test runs. If a stand cannot produce a calibration test that falls into the acceptance bands for the assigned oil within two operationally valid runs, renewing calibration on that stand will require the two-test calibration as listed in C.1.b through C.1.d.

3. Tracking and Reporting Stand ID's

Tracking a stands calibration status will be effected by tracking and reporting to the TMC the instrument (bath) serial number. The cylinder position in a bath is not tracked by the TMC. Instrument ID shall be the instrument serial number and shall not change for the entire history of a TMC monitored test stand (instrument ID variations will be allowed for existing instruments that were calibrated prior to the serial number ID requirement).

4. Reference Oil Assignment:

Of the two tests required to bring a new stand into TMC calibrated status, the calibration test shall be conducted on either reference oil 1007 or oil FOAMB18, and the discrimination run on oil 66, or reblends, or new formulations, as approved by the surveillance panel. Once a stand has attained TMC calibrated status (existing test stand), 100% of the scheduled calibration tests shall be conducted on an assigned blind reference oil sample from the currently accepted set of calibration oils, and the discrimination run on an approved TMC discrimination oil.

5. Calibration Test Evaluation:

The calibration status of the stands will be based on a review of operational parameters for compliance with the test method, followed by a statistical evaluation of the critical parameters test result against the acceptance ranges in Section A (commonly referred to as a Shewhart severity evaluation). Unless otherwise noted, the acceptance bands in Section A are based on a 95% confidence treatment of round robin test results with data exclusions as approved by the surveillance panel. Due to poor test precision on oils above 100 ml Foam Tendency, the severe performing discrimination oil results are not charted but must exceed 100 ml Foam Tendency and have 0 (zero) ml Foam Stability. (The Foam Tendency lower limit is set match the maximum allowable GF-5/6 limit for Foam Tendency, after establishing by round robin and ongoing testing that the oil performance should always exceed that limit.)

6. Removal of Test Stands from the System

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

7. Introduction of New or Re-Blended Reference Oils

Introduction of new or replacement reference oils will be conducted at the discretion of the surveillance panel. Participating laboratories may be asked to donate tests on the new oil(s) to establish baseline performance in the D6082 test. The number of tests requested will be sufficient to rigorously evaluate the oil's performance. Preliminary statistical performance targets and acceptance criteria will be established by the surveillance panel, and those values will be re-assessed as the TMC collects additional calibration data.

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

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

A. Reference Oils and Critical Parameters

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

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

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

*95% Acceptance Bands = Mean +/- (1.960 x sR)

B. Acceptance Criteria

1. New Laboratory/Test Stand(s)

   a. The TMC calibration auditing system calibrates individual test stands (instruments) at individual laboratories. There are no special requirements to bring a LAB into TMC calibrated status, there are only requirements to bring individual test stands into TMC calibrated status, as follows:

   b. A minimum of two (2) operationally valid calibration tests which fall within the acceptance bands for the oils assigned are required to calibrate a stand for the first time. These must be back-to-back consecutive runs on the same test stand, though exceptions can be made at the sole discretion of the TMC for operational fails for reasons that would be considered to have had no bearing on the operational performance of the test stand for subsequent tests (for example, a power failure)

   c. Passing two back-to-back consecutive TMC calibrations places the new test stand in TMC calibrated status. Both tests must pass on operational and statistical criteria.

   d. TMC calibrated status of a test stand is valid for no more than 90 days from date completed of a valid TMC calibration (that is, the end of the test's 24-hour

oxidation heating cycle. To renew the calibration at the end of the calibration period, see Item 2 for Existing Laboratory/Test Stand(s).

2. Existing Laboratory/Test Stand(s)

   a. An existing TMC calibrated test stand, or one where the TMC calibrated status had expired within the past 90 days, can renew its TMC calibrated status by demonstrating a successful calibration on another single TMC blind calibration audit. The test must pass on both operational and statistical criteria.

   b. TMC calibrated status of an existing test stand is valid for no more than 90 days from date completed of a valid TMC calibration (that is, the end of the test's 24--hour oil oxidation heating cycle. Test stands that exceed these time/run specifications are considered to be out of calibration for TMC monitoring purposes.

   c. A stand that has been out of TMC calibration for more than 90 days from the prior TMC calibration expiration date will require New Test Stand calibration as listed in B.1.b through B.1.d. of this document.

   d. A stand must pass the TMC calibration within two operationally valid test runs. If a stand cannot produce a calibration test that falls into the acceptance bands for the assigned oil within two operationally valid runs, renewing calibration on that stand will require the two test calibration as listed in B.1.b through B.1.d.

3. Conversion of 'Dual' Instruments between TEOST-33C and MHT TEOST

   A single instrument can be considered TMC calibrated for only one test method at a time (either D6335 or D7097, never for both simultaneously). If a TMC calibrated instrument is converted for use to or from another test method, the current calibration becomes void at the moment that the physical instrument conversion begins. Renewing calibration on the newly converted stand will require a two-test calibration as listed in B.1.b through B.1.d.

4. Tracking and Reporting Stand Runs

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

      Instrument ID: 1234567
      Run Number: 1234

      Instrument ID shall be the instrument serial number and shall not change for the entire history of a TMC monitored test stand (instrument ID variations will be allowed for existing instruments that were calibrated prior to the serial number ID requirement).

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

5. Reference Oil Assignment:

Of the two tests required to bring a new stand into TMC calibrated status, the tests shall be conducted on reference oil 432 and 434, or reblends as approved by the surveillance panel, assigned in random order. Once a stand has attained TMC calibrated status (existing test stand), 100% of the scheduled calibration tests should be conducted on an assigned blind reference oil from the currently accepted set. A preference for assignment shall be as follows:

Oil	% assigned by instrument
75	50%
435-2	50%

6. Removal of Test Stands from the System

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

7. Introduction of New or Re-Blended Reference Oils

Introduction of new or replacement reference oils will be conducted at the discretion of the surveillance panel. Participating laboratories may be asked to donate tests on the new oil(s) to establish baseline performance in the D6335 (TEOST) test. The number of tests requested will be sufficient to rigorously evaluate the oil's performance (typically a minimum of 12 tests total among all the participating labs). Preliminary statistical performance targets and acceptance criteria will be established by the surveillance panel, and those values will be re-assessed as the TMC collects additional calibration data.

44. D6417 Volatility by Gas Chromatography Test LTMS Requirements

The following are the specific D6417 Volatility by Gas Chromatography Test calibration requirements.

A. Reference Oils and Critical Parameters

The critical pass/fail parameter is Area % Volatility Loss at 371°C. The reference oils, performance targets and acceptance criteria required for the test stand calibration with the TMC are listed in Table 1 and have been approved by the ASTM D02.B0.07 Volatility Surveillance Panel.

Table 1
D6417 (Volatility by GC) Reference Oil Targets and Acceptance Bands Effective 20001002

						Acceptance Bands* 95%	
Test	**Oil Code**	**Parameter**	**n**	**Mean**	**sR**	**Lower**	**Upper**
GC Volatility	52	Area % Volatility Loss	18	6.97	0.31	6.4	7.6
By	55	Area % Volatility Loss	18	11.68	0.51	10.7	12.7
D6417	58	Area % Volatility Loss	18	5.61	0.30	5.0	6.2

*95% Acceptance Bands = Mean +/- (1.960 x sR)

B. Test Stand Defined

1. A test stand is defined as a single channel on a Gas Chromatograph (GC) instrument. If labs wish to calibrate multiple channels in an instrument, each channel must be registered with the TMC as a separate test stand.
2. Tracking and Reporting Stand ID's

   Tracking a stands calibration status will be effected by tracking and reporting to the TMC the instrument serial number and, for instruments with multiple channels, an "F" (Front) or "B" (Back) as a suffix to uniquely identify each channel. Instrument ID shall be the instrument serial number and shall not change for the entire history of a TMC monitored test stand (instrument ID variations will be allowed for existing instruments that were calibrated prior to the serial number ID requirement).

C. Acceptance Criteria

1. New Laboratory/Test Stand(s)
   a. The TMC calibration system calibrates individual test stands (single GC channel) at individual laboratories. There are no special requirements to bring a LAB into TMC calibrated status, there are only requirements to bring individual test stands into TMC calibrated status, as follows:

b. A minimum of two (2) operationally valid calibration tests which fall within the acceptance bands for the oils assigned are required to calibrate a stand for the first time. These must be back-to-back consecutive runs on the same test stand, though exceptions can be made at the sole discretion of the TMC for operational fails for reasons that would be considered to have had no bearing on the operational performance of the test stand for subsequent tests (for example, a power failure).

c. Passing two back-to-back consecutive TMC calibrations places the new test stand in TMC calibrated status. Both tests must pass on operational and statistical criteria.

d. TMC calibrated status of a test stand is valid for no more than 90 days from date completed of a valid TMC calibration (that is, the end of the full elution of the test sample). To renew the calibration at the end of the calibration period, see Item 2 for Existing Laboratory/Test Stand(s).

2. Existing Laboratory/Test Stand(s)

a. An existing TMC calibrated test stand, or one where the TMC calibrated status had expired within the past 90 days, can renew its TMC calibrated status by demonstrating a successful calibration on another single TMC blind calibration audit. The test must pass on both operational and statistical criteria.

b. TMC calibrated status of an existing test stand is valid for no more than 90 days from date completed of a valid TMC calibration (that is, the end of the full test sample elution). Test stands that exceed these time/run specifications are considered to be out of calibration for TMC monitoring purposes.

c. A stand that has been out of TMC calibration for more than 90 days from the prior TMC calibration expiration date will require New Test Stand calibration as listed in C.1.b through C.1.d. of this document.

d. A stand must pass the TMC calibration within two operationally valid test runs. If a stand cannot produce a calibration test that falls into the acceptance bands for the assigned oil within two operationally valid runs, renewing calibration on that stand will require the two-test calibration as listed in C.1.b through C.1.d.

e. Changing the injector flow controller, changing the electronic pneumatic control (EPC) module or changing the flame ionization detector (FID) on a stand for any reason voids the current TMC calibrated status. Renewing calibration on that stand will require a two-test calibration as listed in C.1.b through C.1.d.

3. Reference Oil Assignment

a. Of the two tests required to bring a new stand into TMC calibrated status, the tests shall be conducted on reference oil 55 and either oils 52 or 58, or reblends as approved by the surveillance panel, assigned in random order. Once a stand has attained TMC calibrated status (existing test stand), 100% of the scheduled calibration tests shall be conducted on an assigned blind reference oil sample from the currently accepted set of reference oils. There shall be no preference for

any one reference oil in blind calibration runs, and each shall be assigned for approximately 1/3 of the passing runs on each stand.

4. Mandatory Daily QC Check Sample

   a. All TMC-monitored instruments must utilize TMC reference oil 58 to comply with the Reference Materials section of the ASTM D6417 test method. TMC reference oil 58 is to be run daily, or immediately prior to each session of D6417 runs on each test stand to confirm performance of the test stand before commencing with TMC blind reference, candidate or non-reference runs. The daily QC reference material run must meet the acceptance bands shown in Table 1 for TMC oil 58. If the result falls outside those approved bands, the problem must be resolved, and additional TMC oil 58 runs performed as needed to confirm that the daily QC check sample reliably meets the acceptance range in Table 1. The successful Reference Material run result for the session that includes the TMC blind calibration run is to be reported to the TMC with the blind calibration data using the approved TMC reporting format.

   b. Four-ounce aliquots of TMC oil 58, for use as a D6417 daily QC check fluid, are available for purchase from the TMC.

5. Removal of Test Stands from the System

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

6. Introduction of New or Re-Blended Reference Oils

   Introduction of new or replacement reference oils will be conducted at the discretion of the surveillance panel. Participating laboratories may be asked to donate tests on the new oil(s) to establish baseline performance in the D6417 GC test. The number of tests requested will be sufficient to rigorously evaluate the oil's performance. Preliminary statistical performance targets and acceptance criteria will be established by the surveillance panel, and those values will be re-assessed as the TMC collects additional calibration data.

45. D7097 (MTEOS) Determination of Moderately High Temperature Piston Deposits by Thermo-Oxidation Engine Oil Simulation Test LTMS Requirements

The following are the specific D7097 Determination of Moderately High Temperature Piston Deposits by Thermo-Oxidation Engine Oil Simulation Test calibration requirements.

A. Reference Oils and Critical Parameters

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

Table 1
D7097 (MTEOS) Reference Oil Targets and Acceptance Bands Effective 20060731

						Acceptance Bands* 95%	
Test	**Oil Code**	**Parameter**	**n**	**Mean**	**sR**	**Lower**	**Upper**
MTEOS by D7097	432	Total Deposit wt. (mg)	30	47.04	4.50	38.2	55.9
	434	Total Deposit wt. (mg)	30	27.37	6.57	14.5	40.2
	434-3	Total Deposit wt. (mg)	8	28.39	6.46	15.7	41.0

*95% Acceptance Bands = Mean +/- (1.960 x sR)

B. Acceptance Criteria

1. New Laboratory/Test Stand(s)

a. The TMC calibration auditing system calibrates individual test stands (instruments) at individual laboratories. There are no special requirements to bring a LAB into TMC calibrated status, there are only requirements to bring individual test stands into TMC calibrated status, as follows:

b. A minimum of two (2) operationally valid calibration tests which fall within the acceptance bands for the oils assigned are required to calibrate a stand for the first time. These must be back-to-back consecutive runs on the same test stand, though exceptions can be made at the sole discretion of the TMC for operational fails for reasons that would be considered to have had no bearing on the operational performance of the test stand for subsequent tests (for example, a power failure)

c. Passing two back-to-back consecutive TMC calibrations places the new test stand in TMC calibrated status. Both tests must pass on operational and statistical criteria.

d. TMC calibrated status of a test stand is valid for no more than 90 days from date completed of a valid TMC calibration (that is, the end of the test's 24-hour oxidation heating cycle. To renew the calibration at the end of the calibration period, see Item 2 for Existing Laboratory/Test Stand(s).

2. Existing Laboratory/Test Stand(s)

a. An existing TMC calibrated test stand, or one where the TMC calibrated status had expired within the past 90 days, can renew its TMC calibrated status by demonstrating a successful calibration on another single TMC blind calibration audit. The test must pass on both operational and statistical criteria.

b. TMC calibrated status of an existing test stand is valid for no more than 90 days from date completed of a valid TMC calibration (that is, the end of the test's 24--hour oil oxidation heating cycle. Test stands that exceed these time/run specifications are considered to be out of calibration for TMC monitoring purposes.

c. A stand that has been out of TMC calibration for more than 90 days from the prior TMC calibration expiration date will require New Test Stand calibration as listed in B.1.b through B.1.d. of this document.

d. A stand must pass the TMC calibration within two operationally valid test runs. If a stand cannot produce a calibration test that falls into the acceptance bands for the assigned oil within two operationally valid runs, renewing calibration on that stand will require the two test calibration as listed in B.1.b through B.1.d.

3. Conversion of 'Dual' Instruments between TEOST-33C and MHT TEOST

A single instrument can be considered TMC calibrated for only one test method at a time (either D6335 or D7097, never for both simultaneously). If a TMC calibrated instrument is converted for use to or from another test method, the current calibration becomes void at the moment that the physical instrument conversion begins. Renewing calibration on the newly converted stand will require a two-test calibration as listed in B.1.b through B.1.d.

4. Tracking and Reporting Stand Runs

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

Instrument ID: 1234567

Run Number: 1234

Instrument ID shall be the instrument serial number and shall not change for the entire history of a TMC monitored test stand (instrument ID variations will be allowed for existing instruments that were calibrated prior to the serial number ID requirement).

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

5. Reference Oil Assignment:

   Of the two tests required to bring a new stand into TMC calibrated status, the tests shall be conducted on reference oil 432 and 434, or reblends as approved by the surveillance panel, assigned in random order. Once a stand has attained TMC calibrated status (existing test stand), 100% of the scheduled calibration tests should be conducted on an assigned blind reference oil from the currently accepted set. A preference for assignment shall be as follows:

Oil	% assigned by instrument
432	50%
434	50%

6. Removal of Test Stands from the System

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

7. Introduction of New or Re-Blended Reference Oils

   Introduction of new or replacement reference oils will be conducted at the discretion of the surveillance panel. Participating laboratories may be asked to donate tests on the new oil(s) to establish baseline performance in the D7097 (MTEOS) test. The number of tests requested will be sufficient to rigorously evaluate the oil's performance (typically a minimum of 12 tests total among all the participating labs). Preliminary statistical performance targets and acceptance criteria will be established by the surveillance panel, and those values will be re-assessed as the TMC collects additional calibration data.

46. D7528 ROBO Test LTMS Requirements

The following are the specific D7528 ROBO Test calibration requirements.

A. Reference Oils and Critical Parameters

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

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

D7528 (ROBO) Aged Oil MRV Acceptance Bands, mPa·s and ln(mPa·s)

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

[1] 95% bands in mPa·s are listed for information purposes only; the transformed values will be used to judge acceptance in all cases.
[2] A bias adjustment has been applied to the mean of reference oils 434-2, 434-3, 436 and 438-2 to account for biases observed in the TMC reference data during the periods that each oil target dataset was generated. The 95% confidence range reflects the inclusion of the bias adjustments.
[3] The minimum value for Reference oil 435 is fixed at 60,000 (11.0021 in transformed units) and not a true 95% minimum as calculated from the statistics.
[4]The minimum value for reference oil 435-1 is based on -1.66 standard deviations from the target mean (to match the range previously approved for oil 435 min), so is not actually a 95% confidence range. A 95% confidence range would use 1.96 standard deviations from target mean.

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

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

[1] 95% bands in mPa·s are listed for information purposes only, the transformed values will be used to judge acceptance in all cases.
[2] The minimum value for Reference oil 435 is fixed at 60,000 (11.0021 in transformed units) and not a true 95% minimum as calculated from the statistics.

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

B. Acceptance Criteria

1. New Laboratory/New Test Stand(s)

a. The TMC calibration auditing system calibrates individual test stands at individual laboratories. There are no requirements to bring a lab into TMC calibrated status, there are only requirements to bring individual test stands into TMC calibrated status, as follows:

b. Prior to obtaining calibration test oils from the TMC, new laboratories introducing a test stand must demonstrate their stand can successfully run all three (3) current TMC calibration oils within the TMC acceptance bands. Upon acceptance of these results by the TMC, the lab may request the two test calibration.

c. A minimum of two (2) operationally valid calibration tests which fall within the acceptance bands for the oils assigned are required to calibrate a stand for the first time. These must be back-to-back consecutive runs on the same test

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

d. Passing two back-to-back consecutive TMC calibrations places the new test stand in TMC calibrated status. Both tests must pass on operational and statistical criteria.

e. TMC calibrated status of a test stand is valid for no more than 50 days from date completed of a valid TMC calibration (that is, the end of the test's 40-hour oil oxidation heating cycle), or no more than 15 subsequent test starts on the stand (as counted sequentially by run number; see Item 3), whichever comes first. To renew the calibration at the end of the calibration period, see Item 2 for Existing Laboratory/Test Stand(s).

2. Existing Laboratory/New Test Stand(s)

a. The TMC calibration auditing system calibrates individual test stands at individual laboratories. There are no requirements to bring a lab into TMC calibrated status, there are only requirements to bring individual test stands into TMC calibrated status, as follows:

b. A minimum of two (2) operationally valid calibration tests which fall within the acceptance bands for the oils assigned are required to calibrate a stand for the first time. These must be back-to-back consecutive runs on the same test stand, though exceptions can be made at the sole discretion of the TMC for operational fails for reasons that would be considered to have had no bearing on the operational performance of the test stand for subsequent tests (for example, a power failure).

c. Passing two back-to-back consecutive TMC calibrations places the new test stand in TMC calibrated status. Both tests must pass on operational and statistical criteria.

d. TMC calibrated status of a test stand is valid for no more than 50 days from date completed of a valid TMC calibration (that is, the end of the test's 40-hour oil oxidation heating cycle), or no more than 15 subsequent test starts on the stand (as counted sequentially by run number; see Item 3), whichever comes first. To renew the calibration at the end of the calibration period, see Item 2 for Existing Laboratory/Test Stand(s).

3. Existing Laboratory/Existing Test Stand(s)

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

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

b. TMC calibrated status of an existing test stand is valid for no more than 50 days from date completed of a valid TMC calibration (that is, the end of the test's 40-hour oil oxidation heating cycle), or no more than 15 subsequent test starts (as counted sequentially by run number) on the stand, whichever comes first. Test stands that exceed these time/run specifications are considered to be out of calibration for TMC monitoring purposes.

c. A stand that has been out of TMC calibration for more than 150 days from the prior TMC calibration expiration date will require New Test Stand calibration as listed in B.2.b through B.2.d. of this document.

d. A stand must pass the TMC calibration within two operationally valid test runs. If a stand cannot produce a calibration test that falls into the acceptance bands for the assigned oil within two operationally valid runs. Renewing calibration on that stand will require the two test calibration as listed in B.2.b through B.2.d.

e. Changing the vacuum control valve set point, exchanging the reactor vessel or the vacuum pump, or changing the heating voltage setting by more than ± 1 volt on a stand for any reason voids any current TMC calibrated status. Renewing calibration on that stand will require the two test calibration as listed in B.2.b through B.2.d.

4. Tracking and Reporting Stand Runs

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

Instrument ID: 1

Run Number: 1234

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

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

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

5. Reference Oil Assignment:

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

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

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

6. Removal of Test Stands from the System

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

7. Introduction of New or Re-Blended Reference Oils

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

47. D874 Sulfated Ash LTMS Requirements

The following are the specific D874 Sulfated Ash calibration requirements.

A. Reference Oils and Critical Parameters

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

Table 1
D874 (Sulfated Ash) Reference Oil Targets and Acceptance Bands Effective 20001002

						Acceptance Bands*	
						95%	
Test	**Oil Code**	**Parameter**	**n**	**Mean**	**sR**	**Lower**	**Upper**
Sulfated Ash	90	Mass % Sulfated Ash	27	1.07	0.08	0.91	1.23
by	91	Mass % Sulfated Ash	27	0.82	0.05	0.72	0.92
D874	820-2	Mass % Sulfated Ash	27	1.57	0.08	1.40	1.73

*95% Acceptance Bands = Mean +/- (1.960 x sR)

B. Test Stand Defined

1. This test method does not have a specific instrument or test stand to be calibrated, but rather is a wet-chemistry process. The TMC D874 calibration program is to periodically confirm the expected results of the D874 test process at each participating lab using oils of known performance in the test (reference oils). Therefore, the 'test stand' is defined as the participating lab ID for this test.

C. Acceptance Criteria

1. New Laboratories

a. A minimum of two (2) operationally valid calibration tests which fall within the acceptance bands for the oils assigned are required to calibrate a lab for the first time. These must be simultaneous or consecutive runs, though exceptions can be made at the sole discretion of the TMC for operational fails for reasons that would be considered to have had no bearing on the operational performance of the test stand for subsequent tests.

b. Passing two back-to-back consecutive TMC calibrations places the lab's D874 process in TMC calibrated status. Both tests must pass on operational and statistical criteria.

c. TMC calibrated status of a lab's D874 process is valid for no more than 90 days from date completed of a valid TMC calibration. To renew the calibration at the end of the calibration period, see Item 2 for Existing Laboratory.

2. Existing Laboratory

a. An existing TMC calibrated lab, or one where the TMC calibrated status had expired within the past 90 days, can renew its TMC calibrated status by demonstrating a successful calibration on another single TMC blind calibration audit. The test must pass on both operational and statistical criteria.

b. TMC calibrated status of an existing lab process is valid for no more than 90 days from date completed of a valid TMC calibration (that is, the day of the final ash weighing). Labs that exceed these time/run specifications are considered to be out of calibration for TMC monitoring purposes.

c. A lab that has been out of TMC calibration for more than 90 days from the prior TMC calibration expiration date will require New Laboratory calibration as listed in C.1.a through C.1.c. of this document.

d. A lab must pass the TMC calibration within two operationally valid test runs. If a lab cannot produce a calibration test that falls into the acceptance bands for the assigned oil within two operationally valid runs, renewing calibration on that stand will require the two-test calibration as listed in C.1.a through C.1.c.

3. Tracking and Reporting Lab ID's

a. Tracking a lab's calibration status will be effected by tracking the lab's two letter lab ID, Date Completed and the calibration test sulfated ash results.

4. Reference Oil Assignment:

a. Of the two tests required to bring a new lab into TMC calibrated status, the tests shall be conducted on reference oils listed in Table 1, or reblends or replacement oils as approved by the surveillance panel. Once a lab has attained TMC calibrated status (existing test lab), 100% of the scheduled calibration tests shall be conducted on an assigned blind reference oil sample from the currently accepted set of reference oils. There shall be no preference for any one reference oil in blind calibration runs, and each shall be assigned for approximately 1/3 of the passing runs at each lab.

5. Mandatory QC Check Sample

a. All TMC-monitored instruments must utilize TMC reference oil 90 to comply with the Quality Control sections of D874 test method. The frequency is to be one QC oil run with each batch of routine test samples and the QC test result must be in the approved acceptance range for TMC reference oil 90. A non-

conforming result places the results of the batch of samples run concurrently in question and all must be rerun.

b. One-liter aliquots of TMC oil 90, for use as a D874 daily QC check fluid, are available for purchase from the TMC.

6. Calibration Test Evaluation:

a. The calibration status of the lab will be based on a review of operational parameters for compliance with the test method, followed by a statistical evaluation of the critical parameter test result against the acceptance ranges in Section A, Table 1 (commonly referred to as a Shewhart severity evaluation). Unless otherwise noted, the acceptance bands in Section A are based on a 95% confidence treatment of round robin test results with data exclusions as approved by the surveillance panel.

7. Introduction of New or Re-Blended Reference Oils

Introduction of new or replacement reference oils will be conducted at the discretion of the surveillance panel. Participating laboratories may be asked to donate tests on the new oil(s) to establish baseline performance in the D874 Sulfated Ash test. The number of tests requested will be sufficient to rigorously evaluate the oil's performance. Preliminary statistical performance targets and acceptance criteria will be established by the surveillance panel, and those values will be re-assessed as the TMC collects additional calibration data.

48. D6794 Engine Oil Water Tolerance Test (EOWT) LTMS Requirements

The following are the specific Engine Oil Water Tolerance Test calibration test requirements.

A. Calibration Details

The Engine Oil Water Tolerance Test is calibrated at the laboratory level. No individual instruments are identified in the test method. The test can be run at one of four water treatment rates (0.6%, 1.0%, 2.0%, or 3.0%). Tests targets are maintained by water treatment rate, with each water treatment rate being evaluated separately.

B. Reference Oils and Critical Parameters

The critical parameter is the 20 – 25 mL Average Change in Flow Rate, reported in milliliters per second. The reference oils required for instrument calibration are the reference oils accepted by the ASTM EOWT Surveillance Panel. The mean, standard deviation, and acceptance band for the current reference oils for Average Change in Flow Rate are presented below.

20 – 25 mL AVERAGE CHANGE IN FLOW RATE (CFA)
Unit of Measure: mL/s

0.6% Water Treatment Rate			
Reference Oil	Mean	Standard Deviation	Acceptance Band[A]
77-3	-10.23	2.78	-15.68 to -4.78
79	15.64	4.98	5.89 to 25.40

[A]Test results are compared to the Acceptance Bands

1.0% Water Treatment Rate			
Reference Oil	Mean	Standard Deviation	Acceptance Band[A]
77-3	-7.82	2.34	-12.41 to -3.23
79	13.74	4.84	4.25 to 23.24

[A]Test results are compared to the Acceptance Bands

2.0% Water Treatment Rate			
Reference Oil	Mean	Standard Deviation	Acceptance Band[A]
77-3	-8.80	2.47	-13.65 to -3.95
79	10.16	5.81	-1.23 to 21.55

[A]Test results are compared to the Acceptance Bands

3.0 % Water Treatment Rate			
Reference Oil	Mean	Standard Deviation	Acceptance Band[A]
77-3	-10.15	2.21	-14.49 to -5.82
79	7.83	5.45	-2.85 to 18.52

[A]Test results are compared to the Acceptance Bands

C. Acceptance Criteria

1. New Laboratory

- Operationally valid calibration tests, with results within the Acceptance Bands, must be conducted on each of the reference oils 77-3 and 79, or subsequent approved reblends, at each water treatment rate tested. No candidate oils shall be tested along with these runs.

2. Existing Laboratory

- The laboratory must have been TMC calibrated prior to LTMS introduction or previously accepted into the system by meeting LTMS calibration requirements.
- An operationally valid calibration test, with a result within the Acceptance Band, must be conducted on reference oil 77-3 or 79, or subsequent approved reblends, with each group of candidate test runs, at each water treatment rate tested.

3. Reference Oil Assignment

Once a laboratory has been accepted into the system, the TMC will assign reference oils evenly distributed between 77-3 and 79, or subsequent approved reblends, for continuing calibration at each water treatment rate.

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 Water Tolerance Test, and the response necessary in the case of control chart limit alarms, are depicted below. The Shewhart Chart is used to initially determine the Acceptance Band on a new reference oil, prior to rounding those results to establish the official Acceptance Band for that reference oil.

LUBRICANT TEST MONITORING SYSTEM CONSTANTS

		EWMA Chart				Shewhart Chart	
		LAMBDA		K		K	
Chart Level	Limit Type	Precision	Severity	Precision	Severity	Precision	Severity
Stand	Action	--	--	--	--	--	1.96

The following are steps that must be taken in the case of a result outside the Acceptance Band.

- Result outside the Acceptance Band (all parameters)
  - Conduct an additional calibration test.

5. Introduction of New or Re-Blended Reference Oils

Introduction of new or replacement reference oils will be conducted at the discretion of the surveillance panel. Participating laboratories may be asked to donate tests on the new oil(s) to establish baseline performance in the D6794 EOWT test. The number of tests requested will be sufficient to rigorously evaluate the oil's performance (typically a minimum of 3 tests per lab per treat rate, 12 tests in total, for all the participating labs). Preliminary statistical performance targets and acceptance criteria will be established by the surveillance panel, and those values will be re-assessed as the TMC collects additional calibration data.

49. D6795 Engine Oil Filterability Test (EOFT) LTMS Requirements

The following are the specific Engine Oil Filterability Test calibration test requirements.

A. Calibration Details

The Engine Oil Filterability Test is calibrated at the laboratory level. No individual instruments are identified in the test method.

B. Reference Oils and Critical Parameters

The critical parameter is the 20 – 25 mL Average Change in Flow Rate, reported in milliliters per second. The reference oils required for instrument calibration are the reference oils accepted by the ASTM EOFT Surveillance Panel. The mean, standard deviation, and acceptance band for the current reference oil for Average Change In Flow Rate are presented below.

20 – 25 mL AVERAGE CHANGE IN FLOW RATE (CIFA)
Unit of Measure: mL/s

Reference Oil	Mean	Standard Deviation	Acceptance Band[A]
79	36.58	4.56	27.64 – 45.51

[A]Test results are compared to the Acceptance Bands

C. Acceptance Criteria

1. New Laboratory

   - Two operationally valid calibration tests, with results within the Acceptance Band, must be conducted on reference oil 79, or subsequent approved reblend. No candidate oils shall be tested along with these runs.

2. Existing Laboratory

   - The laboratory must have been TMC calibrated prior to LTMS introduction or previously accepted into the system by meeting LTMS calibration requirements.
   - An operationally valid calibration test, with a result within the Acceptance Band, must be conducted on reference oil 79, or subsequent approved reblend, with each group of candidate test runs.

3. Reference Oil Assignment

   Once a laboratory has been accepted into the system, the TMC will assign reference oil 79, or subsequent approved reblend, for continuing calibration.

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 Filterability Test, and the response necessary in the case of control chart

limit alarms, are depicted below. The Shewhart Chart is used to initially determine the Acceptance Band on a new reference oil, prior to rounding those results to establish the official Acceptance Band for that reference oil.

LUBRICANT TEST MONITORING SYSTEM CONSTANTS

		EWMA Chart				Shewhart Chart	
		LAMBDA		K		K	
Chart Level	Limit Type	Precision	Severity	Precision	Severity	Precision	Severity
Stand	Action	--	--	--	--	--	1.96

The following are steps that must be taken in the case of a result outside the Acceptance Band.

- Result outside the Acceptance Band (all parameters)
  - Conduct an additional calibration test.

5. Introduction of New or Re-Blended Reference Oils

Introduction of new or replacement reference oils will be conducted at the discretion of the surveillance panel. Participating laboratories may be asked to donate tests on the new oil(s) to establish baseline performance in the D6795 EOFT. The number of tests requested will be sufficient to rigorously evaluate the oil's performance (typically a minimum of 3 tests per participating lab). Preliminary statistical performance targets and acceptance criteria will be established by the surveillance panel, and those values will be re-assessed as the TMC collects additional calibration data.

50. D6557 Ball Rust Test (BRT) LTMS Requirements

The following are the specific Ball Rust Test calibration test requirements.

A. Calibration Details

The Ball Rust Test is calibrated at the individual instrument level, by the shaker table used in the test. Shaker tables are identified by ID number within a laboratory and calibrated individually. There is no laboratory level calibration in the Ball Rust Test.

B. Reference Oils and Critical Parameters

The critical parameter is Average Gray Value, reported in brightness units. The reference oils required for instrument calibration are the reference oils accepted by the ASTM Ball Rust Test Surveillance Panel. The mean, standard deviation, and acceptance band for the current reference oils for Average Gray Value are presented below.

AVERAGE GRAY VALUE (AGV)
Unit of Measure: brightness units

Reference Oil	Mean	Standard Deviation	Acceptance Band[A]
1006	128	7.21	114 – 142
82-1	49.2	16.40	17 – 82
86	119.6	10.30	99 – 140
87	121.8	8.50	105 – 139

[A]Test results are compared to the Acceptance Bands

C. Acceptance Criteria

1. New Shaker Table

   - An operationally valid calibration test, with results within the Acceptance Bands, must be conducted on all current reference oils, or subsequent approved reblends. These tests may be run simultaneously. No candidate oils shall be tested along with these runs.

2. Existing Shaker Table

   - The instrument must have been TMC calibrated prior to LTMS introduction or previously accepted into the system by meeting LTMS calibration requirements.
   - An operationally valid calibration test, with results within the Acceptance Bands, must be conducted on an approved reference oil, with every candidate test run on the shaker table.

3. Reference Oil Assignment

   Once a shaker table has been accepted into the system, the TMC will assign an approved reference oil for continuing calibration according to the following proportions:
   - 25% on reference oil 1006 (or subsequent approved reblends)
   - 25% on reference oil 82-1 (or subsequent approved reblends)
   - 25% on reference oil 86 (or subsequent approved reblends)

- 25% on reference oil 87 (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 Ball Rust Test, and the response necessary in the case of control chart limit alarms, are depicted below. The Shewhart Chart is used to initially determine the Acceptance Band on a new reference oil, prior to rounding those results to establish the official Acceptance Band for that reference oil.

LUBRICANT TEST MONITORING SYSTEM CONSTANTS

		EWMA Chart				Shewhart Chart	
		LAMBDA		K		K	
Chart Level	Limit Type	Precision	Severity	Precision	Severity	Precision	Severity
Stand	Action	--	--	--	--	--	1.96

The following are steps that must be taken in the case of a result outside the Acceptance Bands.

- Result outside the Acceptance Band (all parameters)
  - Conduct an additional calibration test.

5. Introduction of New or Re-Blended Reference Oils

Introduction of new or replacement reference oils will be conducted at the discretion of the surveillance panel. Participating laboratories may be asked to donate tests on the new oil(s) to establish baseline performance in the D6557 BRT. The number of tests requested will be sufficient to rigorously evaluate the oil's performance (typically a minimum of 3 tests per lab for all the participating labs). Preliminary statistical performance targets and acceptance criteria will be established by the surveillance panel, and those values will be re-assessed as the TMC collects additional calibration data.

51. D6594 High Temperature Corrosion Bench Test (HTCBT) LTMS Requirements

The following are the specific High Temperature Corrosion Bench Test calibration test requirements.

B. Calibration Details

The High Temperature Corrosion Bench Test is calibrated at the individual instrument level, by the bath used in the test. Baths are identified by ID number within a laboratory and calibrated individually. There is no laboratory level calibration in the High Temperature Corrosion Bench Test.

B. Reference Oils and Critical Parameters

The critical parameters are Copper Concentration and Lead Concentration, reported in milligrams per kilogram. The Change in Copper (Δ Cu) precision is not uniform across reference oils. A natural log transform (ln) is applied to each Δ Cu value before performing statistical evaluations. The reference oils required for instrument calibration are the reference oils accepted by the ASTM High Temperature Corrosion Bench Test Surveillance Panel. The means and standard deviations for the current reference oils for the critical parameters are presented below.

COPPER CONCENTRATION (CUC)
Unit of Measure: ln(mg/kg)

Reference Oil	Mean	Standard Deviation	Acceptance Band[A]
44-4	4.9961	0.1069	120 – 182
1005-5	1.8497	0.3363	3 – 12

[A]Test results are compared to the Acceptance Bands in original units

LEAD CONCENTRATION (PBC)
Unit of Measure: mg/kg

Reference Oil	Mean	Standard Deviation	Acceptance Band
44-4	31.5	9.00	14 – 49
1005-5	9.5	7.60	0 – 24

C. Acceptance Criteria

1. New Instrument

   - Operationally valid calibration tests, with results within the Acceptance Bands, must be conducted on both approved reference oils. No candidate oils shall be tested along with these runs.

2. Existing Instrument

- The instrument must have been TMC calibrated prior to LTMS introduction or previously accepted into the system by meeting LTMS calibration requirements.
- An operationally valid calibration test, with results within the Acceptance Bands, must be conducted on an approved reference oil, with every set of candidate test runs on the instrument.

3. Reference Oil Assignment

Once instruments have been accepted into the system, the TMC will assign reference oil for continuing calibration according to the following proportions:

- 75% on reference oil 1005-5 (or subsequent reblends)
- 25% on reference oil 44-4 (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 the High Temperature Corrosion Bench Test, and the response necessary in the case of control chart limit alarms, are depicted below. The Shewhart Chart is used to initially determine the Acceptance Band on a new reference oil, prior to rounding those results to establish the official Acceptance Band for that parameter.

LUBRICANT TEST MONITORING SYSTEM CONSTANTS

		EWMA Chart				Shewhart Chart	
		LAMBDA		K		K	
Chart Level	Limit Type	Precision	Severity	Precision	Severity	Precision	Severity
Stand	Action	--	--	--	--	--	1.96

The following are steps that must be taken in the case of a result outside the Acceptance Bands.

- Result outside the Acceptance Band (all parameters)
  - Conduct an additional calibration test.

5. Introduction of New or Re-Blended Reference Oils

Introduction of new or replacement reference oils will be conducted at the discretion of the surveillance panel. Participating laboratories may be asked to donate tests on the new oil(s) to establish baseline performance in the D6594 HTCBT. The number of tests requested will be sufficient to rigorously evaluate the oil's performance (typically a minimum of 3 tests per lab for all the participating labs). When possible, a previously approved reference oil should be run alongside the new or re-blended reference oil. Preliminary statistical performance targets and acceptance criteria will be established by the surveillance panel, and those values will be re-assessed as the TMC collects additional calibration data.

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]	$\bar{X}$	s	$\bar{X}$	s	$\bar{X}$	s	$\bar{X}$	s	Maximum	$\bar{X}$	s
1006	6	6-10-00	11-14-01	0.0156989	0.0076717	- -	- -	9.14	0.263	3.29	0.284	20.0	5.41732	0.230855
	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.

Sequence IIIG Reference Oil Targets									
		Effective Dates		PVIS[3]		WPD		ACLW[4]	
Oil	n	From[1]	To[2]	$\overline{X}$	s	$\overline{X}$	s	$\overline{X}$	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 IIIH Reference Oil Targets									
		Effective Dates		Average Piston Varnish		Percent Viscosity Increase		Weighted Piston Deposits	
Oil	n	From[1]	To[2]	$\overline{X}$	s	$\overline{X}$	s	$\overline{X}$	s
434-2[3]	10	07-01-15	10-10-18	9.16	0.34	4.7191	0.4310	4.16	0.70
434-2[4]	46	10-11-18	***	9.16	0.381	4.7191	0.4310	4.16	0.70
434-3[4]	46	07-01-15	11-12-18	9.16	0.381	4.7191	0.4310	4.16	0.70
434-3[5]	11	11-13-18	9-11-23	9.16	0.381	5.7602	0.6598	4.16	0.70
434-3[6]	58	9-12-23	***	9.16	0.300	5.7602	0.5845	4.16	0.42
436[3]	9	07-01-15	10-10-18	9.71	0.100	3.3289	0.3138	4.63	0.28
436[4]	61	10-11-18	9-11-23	9.71	0.124	3.3289	0.3138	4.63	0.28
436[7]	91	9-12-23	***	9.71	0.124	3.3289	0.4005	4.63	0.34
438-1[3]	9	07-01-15	10-10-18	9.39	0.310	3.9754	0.9558	3.66	0.43
438-1[4]	61	10-11-18	***	9.39	0.276	3.9754	0.9558	3.66	0.43
438-2[4]	61	10-11-18	9-11-23	9.39	0.276	3.9754	0.9558	3.66	0.43
438-2[8]	61	9-12-23	***	9.39	0.2889	3.9754	0.4950	3.87	0.26

1 Effective for all tests completed on or after this date
2 *** = Currently in effect
3 Targets based on precision matrix analysis
4 Targets based on all data reported for APV standard deviation only
5 Targets updated for Percent Viscosity Increase only
6 Updated standard deviations.
7 Updated standard deviations for Percent Viscosity Increase and WPD only.
8 Updated target mean for WPD and all standard deviations.

Sequence IIIHA Reference Oil Targets					
		Effective Dates		MRV Viscosity	
Oil	n	From[1]	To[2]	$\overline{X}$	s
434-2[3]	10	07-01-15	***	11.1107	0.5220
434-3	10	07-01-15	11-12-18	11.1107	0.5220
434-3[4]		11-13-18	***		
436[3]	9	07-01-15	9-11-23	9.7854	0.2423
436[5]	91	9-12-23	***	9.7854	0.2864
438-1[3]	9	04-01-15	***	9.8189	0.9132
438-2[3]	9	10-11-18	9-11-23	9.8189	0.9132
438-2[5]	32	9-12-23	***	9.8189	0.6511

1 Effective for all tests completed on or after this date
2 *** = Currently in effect
3 Targets based on precision matrix analysis
4 For oil 434-3 completed after 11-12-18, use Sequence IIIH PVIS Yi value as MRV Yi value.
5 For severity adjustments, targets applied to all tests completed on or after 3-08-22.

Sequence IIIHB Reference Oil Targets					
		Effective Dates		Phosphorus Retention %	
Oil	n	From[1]	To[2]	$\overline{X}$	s
434-2[3]	10	07-01-15	***	79.95	1.58
434-3	10	07-01-15	***	79.95	1.58
436[3]	9	07-01-15	***	94.15	2.02
438-1[3]	9	04-01-15	***	78.92	1.54
438-2	9	09-01-19	***	78.92	1.54

1 Effective for all tests completed on or after this date
2 *** = Currently in effect
3 Targets based on precision matrix analysis

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 IVB Oil Targets							
Oil	n	Effective Dates		AVLI		FeWMEOT	
		From[1]	To[2]	$\overline{X}$	s	$\overline{X}$	s
300	9	10-27-17	***	1.3931	0.2230	5.2645	0.3842
300-1	9	03-04-19	***	1.3931	0.2230	5.2645	0.3842
1011	9	10-27-17	***	1.2538	0.1932	5.0266	0.3508
1011-1	9	11-25-21	***	1.2538	0.1932	5.0266	0.3508
1012	10	10-27-17	***	1.1543	0.1847	4.8344	0.3747

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

Sequence VG Reference Oil Targets														
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
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-

Sequence VH Reference Oil Targets												
Oil	n	Effective Dates		AES		RAC		AEV50		APV50		Hot Stuck Rings
		From[1]	To[2]	$\bar{X}$	s	$\bar{X}$	s	$\bar{X}$	s	$\bar{X}$	s	Maximum Allowable
931	6	20210316	***	8.00	0.60	0.2283	0.5715	8.97	0.30	8.35	0.60	0
940	7	20170128	20221129	6.47	0.49	0.9155	0.2260	8.77	0.28	7.35	0.64	0
940	7	20221130[3]	***	6.47	0.49	0.8041	0.2340	8.77	0.28	7.35	0.64	0
1009	8	20170128	20211115	7.21	0.44	0.0515	0.3139	8.81	0.40	7.89	0.74	0
1011	7	20170128	***	8.43	0.57	-0.5294	0.1924	9.26	0.21	8.67	0.48	0
1011-1	7	20220104	***	8.43	0.57	-0.5294	0.1924	9.43	0.21	8.96	0.48	0

1 Effective for all tests completed on or after this date.
2 *** = currently in effect.
3 Rocker Cover target recalculated for reference oil 940 recalculated using all results on fuel batch DJ0321NX10, number of tests =21, severity adjustments recalculated using new targets.

Sequence IX Oil Targets					
Oil	n	Effective Dates		AVGPIE	
		From[1]	To[2]	$\overline{X}$	s[3]
221	8[4]	4-21-17	6-27-19	3.3819	0.3609
221	8[4]	6-28-19	***	3.3819	0.3775
221-1[5]	--	3-20-25	***	3.3819	0.3775
222	16[4]	4-21-17	***	4.2644	0.2694
224	9	6-28-19	***	2.0445	0.3775
224-1	9	5-1-23	***	2.0445	0.3775
224-2	9	8-9-24	***	2.0445	0.3775

1 Effective for all tests completed on or after this date.
2 *** = currently in effect.
3 Pooled s from matrix analysis.
4 Matrix + additional tests n-size.
5 Targets based on oil 221

Aged Oil LSPI Oil Targets					
		Effective Dates		Average Number of Pre-Ignitions Sqrt (AVPIE+0.5)	
Oil	n	From[1]	To[2]	$\overline{X}$	s
API01	12	2-15-2022	***	1.628	0.4070
API01-1	12	8-27-2024	***	1.628	0.4070
API02	12	2-15-2022	***	3.4085	0.4717
API02-1	12	6-8-2024	***	3.4085	0.4717

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

Sequence X Oil Targets					
Oil	n	Effective Dates		CHST	
		From[1]	To[2]	$\overline{X}$	s[3]
270	14	1-1-17	***	-2.15699	0.17435
271	14	1-1-17	***	-2.60987	0.17537
1011	10	1-1-17	***	-2.08191	0.18882

1 Effective for all tests completed on or after this date.
2 *** = currently in effect.
3 Pooled s from matrix analysis.

Sequence VIE Reference Oil Targets							
Oil	n	Effective Dates		FEI1		FEI2	
		From[1]	To[2]	$\overline{X}$	s^3	$\overline{X}$	s^3
542-2	9	12-13-15	03-13-18	2.56	0.31	1.73	0.30
542-3	9	12-13-15	03-13-18	2.56	0.31	1.73	0.30
544	9	12-13-15	03-13-18	1.30	0.26	1.41	0.20
1010-1	11	12-13-15	03-13-18	1.90	0.27	1.82	0.25
542-2[4,5]	45	03-14-18	***	2.56	0.280	1.73	0.260
542-3[4,5]	45	03-14-18	***	2.56	0.280	1.73	0.260
542-4[6]	45	10-01-19	***	2.56	0.280	1.73	0.260
542-5[6]	45	01-01-23	***	2.56	0.280	1.73	0.260
544[4,5]	43	03-14-18	***	1.30	0.214	1.41	0.256
544-1[6]	43	06-12-25	***	1.30	0.214	1.41	0.256
1010-1[4,5]	39	03-14-18	***	1.90	0.199	1.82	0.327
1010-2[6]	39	01-01-23	***	1.90	0.199	1.82	0.327

1 Effective for all tests completed on or after this date.
2 *** = currently in effect.
3 Pooled s from precision matrix analysis.
4 Pooled s from 134 reference tests completed through 2/19/18 including first run results from the matrix analysis.
5 Targets are also to be applied to the three previous stand results where the industry correction factor was applied to calculate the stand Zi.
6 Targets from previous blend(s) used for this blend.

Sequence VIF Reference Oil Targets							
Oil	n	Effective Dates		FEI1		FEI2	
		From[1]	To[2]	$\overline{X}$	s^3	$\overline{X}$	s^3
542-2[5]	6	11-22-15	12-6-24	2.23	0.18	1.52	0.13
542-3[4,5]	6	11-20-17	12-6-24	2.23	0.18	1.52	0.13
542-4[4,5]	6	09-20-19	12-6-24	2.23	0.18	1.52	0.13
542-5[4,5]	6	01-10-23	12-6-24	2.23	0.18	1.52	0.13
1011	5	11-22-15	12-5-24	1.45	0.14	1.41	0.39
1011	103	12-6-24	***	1.57	0.20	1.46	0.28
1011-1[4]	5	01-13-21	12-5-24	1.45	0.14	1.41	0.39
1011-1	50	12-6-24	***	1.57	0.20	1.46	0.28
543	7	11-22-15	12-5-24	1.88	0.27	2.25	0.34
543	131	12-6-24	***	1.78	0.34	1.99	0.27
543-1[4]	7	5-22-23	12-5-24	1.88	0.27	2.25	0.34
543-1	7	12-6-24	***	1.78	0.34	1.99	0.27

[1] Effective for all tests completed on or after this date.
[2] *** = currently in effect.
[3] Pooled s from precision matrix analysis.
[4] Targets from previous blend(s) used for this blend.
[5] Use of oil suspended by Panel effective 12/6/24

Sequence VIII Reference Oil Targets							
Oil	n	Effective Dates		TBWL		10 Hr. Stripped Viscosity	
		From[1]	To[2]	$\overline{X}$	s	$\overline{X}$	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	5-21-21	13.8	2.14	9.51	0.10
1009-1	4	10-5-23	12-2-24	16.2	3.48	9.73	0.07
1009-1	14	12-3-24	***	14.0	3.38	9.77	0.07

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[3]		TLHC[4]		BSOC	
Oil	n	From[1]	To[2]	$\overline{X}$	s	$\overline{X}$	s	$\overline{X}$	s	$\overline{X}$	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	1-31-04	205.0	34.6	35.3	20.5	1.197	1.213	0.308	0.175
	30[9]	2-1-04	***	205.0	34.6	3.410591	0.563970	1.197	1.213	0.308	0.175
810-2	8[6]	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	1-31-04	273.2	35.5	26.2	19.8	0.454	0.659	0.218	0.053
	30[9]	2-1-04	***	273.2	35.5	3.077855	0.362927	0.454	0.659	0.218	0.053
811-2[8]	20	11-26-06	1-31-04	281.5	37.4	24.7	21.6	0.366	0.6	0.223	0.052
	20[9]	2-1-04	***	281.5	37.4	2.961267	0.361554	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[5]	--	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[7]	--	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	1-31-04	190.7	24.7	23.9	14.6	0.1806	0.3977	0.148	0.038
	16[9]	2-1-04	***	190.7	24.7	3.059337	0.581279	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 TGF is ln(TGF+1).
4 Transformation for TLHC is ln(TLHC+1).
5 Initial targets based on 1004-1.
6 Three runs on 810-1 and five runs on 810-2.
7 Initial targets based on 1004-2.
8 Initial targets based on 811-1
9 Targets valid for 1Y3998 liners only

1P Reference Oil Targets													
		Effective Dates		TGC		TLC		AOC[1]		WDP		EOTOC[2]	
Oil	n	From	To[3]	$\bar{X}$	s	$\bar{X}$	s	$\bar{X}$	s	$\bar{X}$	s	$\bar{X}$	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]	$\bar{X}$	s	$\bar{X}$	s	$\bar{X}$	s	$\bar{X}$	s	$\bar{X}$	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
831-3[4]	--	06-16-15	***	46.02	5.90	21.87	7.89	5.5089	0.7141	2.8828	0.2900
831-4[4]	--	05-19-20	***	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

C13 Aeration Reference Oil Targets					
Oil	n	Effective Dates		40 - 50 Hour Average Aeration %	
		From	To[1]	$\overline{X}$	s
PC11G	5	11-01-2014	***	10.67	0.203
PC11H	3	11-01-2014	***	12.14	0.285
PC11I	3	11-01-2014	***	10.92	0.139
PC11J	6	11-01-2014	***	10.60	0.203
PC11K	7	11-01-2014	***	11.94	0.285
PC11L	6	11-01-2014	***	10.73	0.139
832(PC11G)	-	5-01-2015	2-01-2018	10.67	0.203
832-1	4	02-02-2018	***	10.23	0.2774
833(PC11K)	--	4-01-2015	2-01-2018	11.94	0.285
833-1	5	02-02-2018	***	11.94	0.2774

1 *** = currently in effect

ISB Reference Oil Targets							
		Effective Dates		Average Camshaft Wear		Average Tappet Weight Loss	
Oil	n	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	10-18-17	42.5	5.0	97.2	14.8
831-1[2]	--	10-19-17	***	42.5	8.7	97.2	14.8
831-2[2]	--	8-6-13	10-18-17	42.5	5.0	97.2	14.8
831-2[2]	--	10-19-17	***	42.5	8.7	97.2	14.8
831-3[2]	--	8-11-15	10-18-17	42.5	5.0	97.2	14.8
831-3[2]	--	10-19-17	9-03-20	42.5	8.7	97.2	14.8
831-3	--	9-4-20	6-30-21	52.4	9.2	97.2	14.8
831-1[3]	--	7-1-21	***	3.7495	0.2302	9.8590	1.1755
831-4[2]	--	6-14-17	10-18-17	42.5	5.0	97.2	14.8
831-4[2]	--	10-19-17	9-03-20	42.5	8.7	97.2	14.8
831-4	--	9-4-20	6-30-21	52.4	9.2	97.2	14.8
831-4[3]	--	7-1-21	***	3.7495	0.2302	9.8590	1.1755
835[3]	8	7-1-21	***	3.9338	0.2302	9.7057	1.1755

1 *** = currently in effect
2 Targets based on oil 831
3 Transformed units LN(ACSW) and SQRT(ATWL)

ISBV108 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
834	14	4-20-2014	***	3.81	0.22	4.40	0.257	4.48	0.296	7522	373.5

1 Effective for all tests completed on or after this date.

ISBV156 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
822-2	11	4-20-24	***	3.07	0.271	6.09	0.301	6.46	0.293	14125	827.9

1 Effective for all tests completed on or after this date.

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
830-3	5	4-16-20	***	5.1	1.5	2.9653	0.3274	8.24	0.50	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]
1005-4[7]	--	02-04-15	***	5.01[7]	0.56[7]
1005-5[7]	--	02-04-15	***	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]	$\bar{X}$	s	$\bar{X}$	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]
1005-5[6]	--	02-04-15	***	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-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	7-29-2020	4.09	0.20	5.81	0.50	6.48	0.61	13948	584
	57	7-30-2020	***	4.09	0.20	5.81	0.50	6.48	0.61	13948	1156

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]	$\overline{X}$	s	$\overline{X}$	s	$\overline{X}$	s	$\overline{X}$	s	$\overline{X}$	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

T-13 Reference Oil Targets							
		Effective Dates		IR Oxidation Peak Height absorbance / cm		% Increase in Viscosity at 40°C from 300 to 360 hour[2]	
Oil	n	From[1]	To[2]	$\overline{X}$	s	$\overline{X}$	s
PC11A	6	10-01-2014	11-24-2015	142.7	12.4	9.303	1.212
PC11A	6	11-25-2015	***	127.4	11.1	8.610	0.929
PC11B	3	10-01-2014	***	59.7	12.4	4.690	1.212
PC11C	4	10-01-2014	***	121.1	12.4	8.146	1.212
PC11D	7	10-01-2014	***	133.5	12.4	8.676	1.212
PC11E	7	10-01-2014	***	59.2	12.4	4.606	1.212
PC11F	4	10-01-2014	***	123.6	12.4	9.044	1.212
823(PC11A)	-	05-01-2015	11-24-2015	142.7	12.4	9.303	1.212
823(PC11A)	-	11-25-2015	***	127.4	11.1	8.610	0.929
823-1	5	05-01-2023	***	109.3	11.1	8.139	0.929
824	8	12-01-2024	***	48.03	11.8	3.699	0.970

1 Effective for all tests completed on or after this date.
2 *** = currently in effect
3 SQRT Transformation adopted 20151019

Roller Follower Wear Test Reference Oil Targets						
Engine Type	Oil	n	Effective Dates		Average Wear	
			From[1]	To[2]	$\bar{X}$	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
	1005-5[8]	--	02-18-16	***	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					
Oil	n	Effective Dates		MRV Viscosity	
		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

DD13 Reference Oil Targets					
Oil	n	Effective Dates		Hours to Scuff	
		From[1]	To[2]	$\overline{X}$	s
864	12[3]	1-1-15	***	48	26
866	12[3]	1-1-15	***	33	26
DD13X	12	1-1-15	***	48	26
DD13C	12	1-1-15	***	33	26

1 Effective for all tests completed on or after this date.
2 *** = currently in effect.
3 n-size is based on 12 DD13 precision matrix tests

L-33-1 Reference Oil Targets						
			Effective Dates		Rust	
Oil	Gear Version	n	From[1]	To	$\overline{X}$	s
121	V94.1	12[2]	6-5-96	4-19-00	9.370[2]	0.280[2]
	V95.1	12[2]	6-5-96	4-19-00	9.370[2]	0.280[2]
121-1	V94.1	--	1-19-98	4-29-99	9.370[3]	0.280[3]
	V94.1	45[2]	4-30-99	11-17-00	9.390[2]	0.218[2]
	V95.1	--	1-19-98	4-29-99	9.370[3]	0.280[3]
	V95.1	45[2]	4-30-99	11-17-00	9.390[2]	0.218[2]
	V99.1	8	4-20-00	11-17-00	9.830	0.260[4]
121-2	V94.1	--	12-14-99	11-17-00	9.390[5]	0.218[5]
	V95.1	--	12-14-99	11-17-00	9.390[5]	0.218[5]
	V99.1	--	4-20-00	11-17-00	9.830[6]	0.260[4]
123	V94.1	54[2]	5-5-95	4-19-00	9.000[2]	0.330[2]
	V95.1	54[2]	5-5-95	4-19-00	9.000[2]	0.330[2]
	V99.1	12	6-11-02	8-24-04	8.430	0.390
	V01.1	--	11-25-02	8-24-04	8.430[10]	0.390[10]
	V99.1 & V01.1	30	8-25-04	***	8.560	0.230
123-1	V94.1	13[7]	4-20-00	11-17-00	8.240[7]	0.330[8]
	V95.1	--	12-14-99	4-19-00	9.000[9]	0.330[9]
	V95.1	13[7]	4-20-00	11-17-00	8.240[7]	0.330[8]
	V99.1	13[7]	4-20-00	11-17-00	8.240[7]	0.330[8]
123-2	V99.1	--	11-25-02	8-24-04	8.430[10]	0.390[10]
	V99.1 & V01.1	--	8-25-04	6-1-06	8.560[9]	0.230[9]
	V99.1 & V01.1	15	6-2-06	***	8.740	0.260
	AAM K2XX	10	6-24-16	06-28-17	8.05	0.43
	AAM K2XX	19	6-29-17	11-07-17	8.09	0.41
	AAM K2XX	22	11-08-17	0-01-20	8.12	0.38
	AAM K2XX	19	01-02-20	08-31-20	8.37	0.39
	K2XX & T1XX	37	09-01-20	***	8.51	0.35
126	T1XX	6	02-22-23	***	8.90	0.27
151-3	V99.1	13	6-11-02	8-24-04	9.690	0.350
	V01.1	--	11-25-02	8-24-04	9.690[11]	0.350[11]
	V99.1 & V01.1	30	8-25-04	***	9.640	0.250
155	V99.1 & V01.1	--	6-2-06	---	9.580	0.250[12]
155-1	V99.1 & V01.1	--	4-4-12	---	9.580	0.250[12]
	AAM K2XX	9	6-24-16	06-28-17	9.26	0.12
	AAM K2XX	20	6-29-17	11-07-17	9.24	0.19
	AAM K2XX	23	11-08-17	01-01-20	9.25	0.22
	AAM K2XX	20	01-02-20	08-31-20	9.47	0.13
	K2XX & T1XX	42	09-01-20	***	9.47	0.16
155-2	K2XX & T1XX	-	08-25-21	***	9.47	0.16

1 Effective for all tests completed on or after this date.
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		
	Pinion Batch	Oil	n	From	To	$\bar{X}$	s	Bands	$\bar{X}$	s	Bands	$\bar{X}$	s	Bands	$\bar{X}$	s	Bands
MNP-COATED	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	20180606	7.00	1.155	4 - 10	7.00	1.414	4 - 10	8.83	0.974	7 - 10	6.00	0.242	5 - 7
			14	20180607	***	7.214	0.802	6 - 8	7.429	1.284	6 - 9	9.364	1.302	7 - 10	6.357	0.497	6 - 7
		152-1	6	19000101	20180606	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
			24	20180607	***	6.5	1.769	4 – 9	8.792	0.833	8 – 10	8.533	1.72	6 – 10	6.208	0.833	5 - 7
		152-2	6	19000101	20180606	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
			24	20180607	***	6.5	1.769	4 – 9	8.792	0.833	8 – 10	8.533	1.72	6 – 10	6.208	0.833	5 - 7
		155	8	19000101	20180606	8.29	0.488	7 - 10	8.86	0.690	7 - 10	9.90	0.436	9 - 10	6.86	0.378	6 - 8
			14	20180607	***	8.286	0.825	7 – 9	8.786	0.699	8 – 10	9.893	0.027	9.8 – 9.9	6.929	0.267	6 – 7

L-37 Reference Oil Targets																	
						Ridging			Rippling			Spitting			Wear		
	Pinion Batch	Oil	n	From	To	$\overline{X}$	s	Bands	$\overline{X}$	s	Bands	$\overline{X}$	s	Bands	$\overline{X}$	s	Bands
UNCOATED	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

L-37 Reference Oil Targets																	
						Ridging			Rippling			Spitting			Wear		
	Pinion Batch	Oil	n	From	To	$\overline{X}$	s	Bands	$\overline{X}$	s	Bands	$\overline{X}$	s	Bands	$\overline{X}$	s	Bands
UNCOATED	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	20180606	6.40	1.673	3 - 9	8.40	0.894	6 - 10	3.80	1.483	1 - 7	5.60	0.894	4 - 8
			11	20180607	***	6.128	1.328	4 - 8	8.364	0.809	7 - 9	4.364	3.491	0 - 10	5.545	0.820	5 - 7
		152-1	8	19000101	20180606	8.75	0.707	7 - 10	8.63	0.916	7 - 10	9.45	1.003	7 - 10	7.00	0.500	6 - 8
			12	20180607	***	7.583	1.832	5 - 10	8.917	0.669	8 - 10	8.883	1.872	6 - 10	6.5	0.522	6 - 7
		152-2	8	19000101	20180606	8.75	0.707	7 - 10	8.63	0.916	7 - 10	9.45	1.003	7 - 10	7.00	0.500	6 - 8
			12	20180607	***	7.583	1.832	5 - 10	8.917	0.669	8 - 10	8.883	1.872	6 - 10	6.5	0.522	6 - 7
		155	9	19000101	20180606	8.56	0.882	7 - 10	8.44	1.014	6 - 10	8.70	1.578	5 - 10	6.78	0.441	6 - 8
			14	20180607	***	8.714	0.611	8 - 9	8.714	0.726	8 – 10	9.514	1.038	8 - 10	6.714	0.469	6 - 7

L-37-1 Reference Oil Targets

Hardware	Pinion Batch	Oil	n	From[1]	To[2]	Ridging			Rippling			Spitting			Wear		
						$\overline{X}$	s	Bands	$\overline{X}$	s	Bands	$\overline{X}$	s	Bands	$\overline{X}$	s	Bands
UNCOATED	Gleason 04-2014	134/134-1	6	20170503	20190630	3.8	1.2	-	7.8	1.2	-	7.7	1.9	-	4.8	1.2	-
		152-2	8	20170503	20190630	9.3	0.7	-	8.9	1.6	-	9.9	0.0	-	7.8	0.9	-
		155-1	7	20170503	20190630	9.6	0.5	-	9.6	0.5	-	9.9	0.0	-	7.9	0.7	-
	Gleason 04-2014	134/134-1	10	20190701	20190806	3.8	0.9	-	7.2	1.3	-	7.9	1.5	-	5.1	1.0	-
		152-2	11	20190701	20190806	9.3	0.6	-	8.7	1.4	-	9.9	0.1	-	7.5	0.8	-
		155-1	11	20190701	20190806	9.6	0.5	-	8.7	1.3	-	9.9	0.0	-	7.5	0.7	-
	Gleason 04-2014,06-2018	134/134-1	14	20190807	20200520	3.9	0.9	-	7.1	1.5	-	8	1.7	-	5.1	0.9	-
		152-2	15	20190807	20200520	9.3	0.6	-	8.7	1.3	-	9.9	0.1	-	7.5	0.8	-
		155-1	16	20190807	20200520	9.6	0.5	-	8.8	1.1	-	9.9	0.0	-	7.6	0.7	-

L-37-1 Reference Oil Targets																		
Hardware	Pinion Batch	Oil	n	From[1]	To[2]	Ridging			Rippling			Spitting			Wear			
						$\overline{X}$	s	Bands	$\overline{X}$	s	Bands	$\overline{X}$	s	Bands	$\overline{X}$	s	Bands	
UNCOATED	Gleason 04-2014, 06-2018, 2019/20	134/134-1	24	20200521	***	4.1	0.9	-	7.4	1.4	-	7.9	2.0	-	5.3	0.9	-	
		152-2	28	20200521	***	9.0	0.8	-	8.3	1.2	-	9.9	0.1	-	7.6	0.7	-	
		155-1/155-2	21	20200521	***	9.5	0.5	-	8.6	1.1	-	9.9	0.0	-	7.5	0.7	-	
MNP-COATED	Gleason 04-2014	134/134-1	12	20191001	***	6.1	2.4	-	7.4	1.6	-	9.9	0.1	-	6.8	0.9	-	
		152-2	9	20191001	***	9.7	0.5	-	9.3	0.5	-	9.7	0.6	-	8.2	0.7	-	
		155-1/155-2	9	20191001	***	9.3	1.0	-	8.7	0.7	-	9.9	0.0	-	7.9	0.8	-	
	Gleason 04-2021	134/134-1	6	20230510	***	-	-	4 - 6	-	-	5 - 8	-	-	9.8-9.9	-	-	6 - 7	
		152-2	5	20230510	***	-	-	8 – 10	-	-	7 – 9	-	-	9.9-10.0	-	-	7 – 8	
		155-1/155-2	7	20230510	***	-	-	8 – 10	-	-	7 – 9	-	-	9.8-10.0	-	-	7 – 8	

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

L-42 Reference Oil Targets						
			Effective Dates		Coast Side Pinion Scoring	
Oil	Gear Batch	N	From[1]	To[2]	$\overline{X}$	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]

L-42 Reference Oil Targets (continued)						
Oil	Gear Batch	N	Effective Dates		Coast Side Pinion Scoring	
			From[1]	To[2]	$\overline{X}$	s
116-1	P8L123[7]	--	3-1-09	***	22.9	4.81
	P8L205[7]	--	3-1-09	***	22.9	4.81
	P8L327[7]	--	3-1-09	***	22.9	4.81
	P8L604[7]	--	3-1-09	***	22.9	4.81
	P4L806[7]	--	3-1-09	***	25.1	5.49
	P8L119	10	3-22-09	***	23.0	5.49[8]
	P8T025A	10	4-17-12	***	23.0[9]	5.49[9]
	P8AD078X	10	3-7-15	***	23.0[9]	5.49[9]
117	P8T025A	10	5-29-14	***	23.0[10]	5.49[10]
	P8AD078X	10	3-7-15	***	23.0[9,10]	5.49[9,10]
	P8AD132 (Pinion ID's C1L446, C1L637)	10	11-9-17	***	23.0[9,10]	5.49[9,10]
	P2DA01	10	10-30-23	***	23.0[9,10]	5.49[9,10]

1 Effective for all tests completed on or after this date	6 Targets based on gear batch P8L604
2 ***currently in effect	7 Targets based on oil 116
3 Targets based on oil 114	8 Standard deviation based on gear batch P4L806
4 Targets based on oil 114-1	9 Carried over from previous hardware batch
5 Targets based on gear batch P8L327	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 Reference Oil Targets													
		Effective Dates		Viscosity Increase		Pentane Insolubles		Toluene Insolubles		Average Carbon/Varnish		Average Sludge	
Oil	n	From[1]	To[2]	$\overline{X}$	s^3	$\overline{X}$	s^3	$\overline{X}$	s^3	$\overline{X}$	s^3	$\overline{X}$	s^3
131-3	30	6-3-94	***	81.451	7.659	2.293	0.413	0.554	0.249	1.111	0.511	9.411	0.106
131-4	--	11-2-95	***	75.944	7.659	2.560	0.413	0.923	0.249	1.053	0.511	9.483	0.106
133	9	8-23-00	***	93.691	7.659	2.801	0.413	1.405	0.249	6.548	0.511	9.381	0.106
143	30	6-3-94	***	31.500	7.659	1.271	0.413	0.914	0.249	9.002	0.511	9.503	0.106
145	8	2-26-25	***	70.225	5.099	1.198	0.249	1.217	0.409	6.329	0.747	8.575	0.648
148	30	6-3-94	***	36.966	7.659	0.387	0.413	0.257	0.249	8.306	0.511	9.532	0.106
148-1	--	3-11-02	8-9-23	36.966	7.659	0.387	0.413	0.257	0.249	8.306	0.511	9.532	0.106
151-2	9	8-23-00	***	37.070	2.717	2.064	0.380	1.329	0.394	8.801	0.517	9.382	0.106
155-1	17	6-7-14	2-10-16	27.176	3.127	1.388	0.372	1.035	0.451	8.971	0.436	9.441	0.106
155-1	20	2-11-16	8-11-16	27.750	3.242	1.490	0.529	1.135	0.639	8.875	0.678	9.435	0.103
155-1	35	8-12-16	9-15-23	28.800	3.669	1.509	0.434	1.109	0.530	8.760	0.586	9.426	0.101
155-2	35	8-1-23	2-20-24	28.800	3.669	1.509	0.434	1.109	0.530	8.760	0.586	9.426	0.101
155-2	35	8-1-23	***	23.000	2.832	1.509	0.434	1.109	0.530	8.760	0.708	9.426	0.101

1 Effective for all tests completed on or after this date.
2 *** = currently in effect.
3 Standard deviations are pooled s values for all oils except 145, 151-2, 155-1, and 155-2.
4 155-2 Target Update on Feb 21, 2024 applied retroactively to all 155-2 runs since August 1, 2023.

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]
170	12	Nitrile	1-24-16	8-20-18	-72.75	3.416	1.500	0.674	2.275	0.449
	32	Nitrile	8-21-18	9-9-24	-70.68	3.007	2.325	0.341	1.500	0.718
	32	Nitrile	9-10-24	***	-70.68	3.007	1.500	0.718	2.325	0.341
171	3	Polyacrylate	8-21-18	5-26-20	24.167	20.929	0.333	0.577	-0.233	0.306
171	3	Fluoroelastomer	8-21-18	5-26-20	-42.6	4.2	-0.667	0.577	1.467	0.306
171	40	Polyacrylate	5-27-20	***	25.090	11.415	0223	1.858	-0.088	1.096
171	39	Fluoroelastomer	5-27-20	***	-47.949	5.947	0.987	1.664	2.167	1.201

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.

D5133 (GI) Test Reference Oil Targets					
		Effective Dates		Gelation Index	
Oil	n	From[1]	To[2]	$\overline{X}$	s
1009	16	20030715	***	7.3	0.68
51	10	19960401	19961231	65.4	12.6
51	35	19970101	20010702	63.3	12.01
52	11	19960401	19961231	4.4	0.20
52	35	19970101	20030714	4.5	0.24
53	11	19960401	19961231	45.3	3.70
53	37	19970101	20030714	44.7	4.64
55	10	19960401	19961231	22.6	5.10
55	36	19970101	20010702	22.3	4.84
58	17	20011024	20200930	5.8	0.69
58[3]	17	20201001	***	<6.0	N/A
62	10	19960401	19961231	15.7	4.70
62	35	19970101	***	17.0	3.90
GIA17	18	20190409	***	19.0	1.87
GIC18	13	20221027	***	10.3	1.21

[1] Effective for all tests completed on or after this date.
[2] *** = currently in effect.
[3] Discrimination Oil

D5800 Volatility by Noack Test Reference Oil Targets					
		Effective Dates		Sample Evaporation Loss	
Oil	n	From[1]	To[2]	$\overline{X}$	s
51	NA	***	20000925	18.13	0.42
52	NA	***	20000925	13.39	0.40
	59	20000926	20030720	13.61	0.49
	33	20030721	20131011	13.75	0.61
53	NA	***	20000925	22.30	0.55
54	NA	***	20000925	23.54	0.67
55	NA	***	20000925	16.21	0.48
	60	20000926	20030720	16.39	0.66
	32	20030721	20131011	17.09	0.76
58	59	20000926	20030720	14.46	0.52
	37	20030721	20131011	15.20	0.72
VOLC12	24	20130918	***	14.19	0.73[3]
VOLD12	27	20130918	***	12.52	0.73[3]
VOLE12	27	20130918	***	16.74	0.73[3]

1 Effective for all tests completed on or after this date.
2 *** = currently in effect.
3 based on a pooled standard deviation of data from 2014-2016

D6082 High Temperature Foam Test Reference Oil Targets							
		Effective Dates		Foam Tendency		Foam Stability	
Oil	n	From[1]	To[2]	$\overline{X}$	s	$\overline{X}$	s
1002	32	19000101	20020617	410.63	58.78	37.81	45.41
1007	28	19981112	20060327	65.71	19.28	0	0
	28	20060328	***	66	19	0	0
FOAMB18	18	20180807	***	54	9	0	0

3 Effective for all tests completed on or after this date.
4 *** = currently in effect.

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

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

D6417 Volatility by Gas Chromatography Test Reference Oil Targets					
		Effective Dates		Area % Volatized	
Oil	n	From[1]	To[2]	$\bar{X}$	s
52	18	20001002	***	6.97	0.31
55	18	20001002	***	11.68	0.51
58	18	20001002	***	5.61	0.3

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

D7097 (MTEOS) Moderately High Temperature Piston Deposits by Thermo- Oxidation Engine Oil Simulation Test Reference Oil Targets					
		Effective Dates		Total Deposits	
Oil	n	From[1]	To[2]	$\bar{X}$	s
74	7	20000801	20010531	15.6	5.5
	20	20010601	20031031	16.84	5.28
	14	20031101	20050629	13.59	3.97
	17	20050630	20060730	12.74	4.6
	30	20060731	20130204	12.85	5.59
432	7	20000801	20010531	50.51	5.5
	18	20010601	20031031	50.13	4.88
	8	20040218	20050629	45.18	2.73
	14	20050630	20060730	47.99	3.67
	30	20060731	20090125	47.04	4.5
	30	20090126	20090412	47.04	4.5
	30	20090413	***	47.04	4.5
433	7	20000801	20010531	52.56	5.5
	18	20010601	20031031	50.28	5.26
	14	20031101	20050111	42.1	5.34
434	8	20050112	20050629	30.51	2.89
	11	20050630	20060730	27.68	5.57
	30	20060731	***	27.37	6.57
1006	7	20000801	20010531	34.94	5.5
	24	20010601	20031031	34.53	5.93
	14	20031101	20050111	42.43	6.1

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

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

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

D874 Test Reference Oil Targets					
		Effective Dates		Sulfated Ash, mass %	
Oil	n	From[1]	To[2]	$\overline{X}$	s
90	27	20070206	***	1.07	0.08
91	27	20070726	***	0.82	0.50
830-2	27	20070726	***	1.57	0.80

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

History of Industry Correction Factors
Appendix B

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
IIIH	July 1, 2015	***	All Tests	None
IIIHA	July 1, 2015	***	All Tests	None
IIIHB	July 1, 2015	***	All Tests	None
IVA	None		All Tests	None
IVB	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.
	All tests using fuel batch DJ0121NX10			None
VH	All reference tests using fuel Batches GI0321NX10 and GI0321NX10-1			Subtract 0.32 from AES result

History of Industry Correction Factors
Appendix B

Test Area	Effective		Condition	Correction
	From	To		
VH	March 16, 2021	Batches GI0321NX10 and GI0321NX10-1	Non reference tests	Subtract 0.32 from AES results for all non-reference oil tests completing on or after 3/16/21
IX	None		All Tests	None
IX Aged	None		All Tests	None
X	None		All Tests	None
Test Area	Effective		Condition	Correction
	From	To		
VIE	March 14, 2018 to ****		All Tests as noted adjacent	Add +0.21 to FEI1 and +0.22 to FEI2 Apply to Reference Tests completing on or after 3/14/18 Apply to Non reference tests on stand/engines referenced with correction factor applied. Apply correction factors to three previous reference tests completing before 3/14/18 in a given stand for purposes of Zi calculation.
VIF	None		All Test	None
VIII	October 5, 2023 to ****		All Tests	Add -0.14 to 10-Hour Stripped Viscosity and -3.6 to Total Bearing Weight Loss to all tests completing on or after October 5, 2023.

History of Industry Correction Factors
Appendix B

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	March 31,2015	All Tests	Add -0.451 to ln(TLHC+1)
	April 1,2015	***	All Tests on 1Y3998 Liners	Add 0.419954 to ln(TGF+1)
1P	None		All Tests	None
1R	None		All Tests	None
C13	None		All Tests	None
COAT	20190510	***	Batch A Oil Filters	Multiply AAVE4050 by 0.9606
	20221118	***	Batch B Oil Filters	Multiply AAVE4050 by 0.9310
ISB	April 21, 2011	October 18, 2017	All tests using batch B tappets with batch E, F, and G cams	Multiply ATWL by 0.637; Add -9.5 to ACSW
	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
	November 13, 2012	October 18, 2017	All tests using batch C tappets with batch H and J cams	Multiply ATWL by 0.711; Add -5.6 to ACSW
	None	October 18, 2017	All test using batch D tappets and batch K cams	Multiply ATWL by 1; Add -11.3 to ACSW
	October 19, 2017	September 3,2020	All tests using batch K cams with batch D tappets and batch E crossheads	Multiply ATWL by 0.7851; Add -18.5 to ACSW
	September 4, 2020	***	All tests using batch K cams with batch D tappets	Multiply ATWL by 0.7851; Multiply ACSW by 0.94
	September 4, 2020	***	All tests using batch L cams with batch E tappets	Multiply ATWL by 0.7851; Multiply ACSW by 0.77
	September 4, 2020	June 30, 2024	All tests using batch M cams with batch F tappets and batch F crossheads (and subsequent batches)	Multiply ATWL by 0.92; Multiply ACSW by 0.77
	July 1, 2025	***	All tests using batch F tappets (and subsequent batches)	Add -0.741 to SQRT(ATWL) Add -0.4552 to LN(ACSW)

Test Area	Effective		Condition	Description
	From	To		
ISM	June 28, 2007	March 3,2010	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	April 29,2011	All Tests	Add +1.3 to Crosshead Wear At 3.9% Soot
	April 30, 2011	***	All tests on crosshead batches through batch F	Add +2.5 to Crosshead Wear At 3.9% Soot
	November 19, 2013	September 30, 2014	All Tests	Add -0.200 to ln(SAIAS)
	October 1, 2014	***	All Tests	Add 4 kPa to Oil Filter Delta Pressure
			All tests using batch C injector push rods, batch D injector adjusting screws and batch F crossheads	Add + 0.410 to ln(SAIAS)
	January 1, 2020	***	All tests using batch G crossheads	Add +0.6 to Crosshead Wear At 3.9% Soot
	***	***	All tests using batch C injector push rods, batch E injector adjusting screws, batch G and subsequent batch crossheads	Add + 0.250 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-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.
				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[$(\ln(OC_{100\text{-}300}) \times 0.961)$]

Test Area	Effective		Condition	Description
	From	To		
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)]

Test Area	Effective		Condition	Description
	From	To		
T-12	***	***	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)]
	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)]
	August 4, 2015	***	All test using VUXOA or VUXOB Hardware	Multiply Average Top Ring Weight Loss by 0.912
				Multiply Average Cylinder Liner Wear by 0.953
				$\Delta Lead\ (250\text{-}300)_{Final}$ = exp[(ln(ΔLead 250-300) x 0.895)]
				$\Delta Lead_{Final}$ = exp[(ln(ΔLead) x 0.954)]
				OC = exp[(ln($OC_{100\text{-}300}$) x 0.942)]
	February 25, 2016	***	All test using VUYPx	Multiply Average Top Ring Weight Loss by 0.912
				Multiply Average Cylinder Liner Wear by 0.970
				If $OC_{100\text{-}300} > 65.0$ $\Delta Lead(250\text{-}300)_{Final}$ = exp[(ln(ΔLead(250-300) + (65.0 - $OC_{100\text{-}300}$) x 0.04021)] If $OC_{100\text{-}300} \leq 65.0$ $\Delta Lead(250\text{-}300)_{Final}$ = ΔLead(250-300)
				If $OC_{100\text{-}300} > 65.0$ $\Delta Lead_{Final}$ = exp[(ln(ΔLead) + (65.0 - $OC_{100\text{-}300}$) x 0.03088] If $OC_{100\text{-}300} \leq 65.0$ $\Delta Lead_{Final}$ = ΔLead
				OC = exp[(ln($OC_{100\text{-}300}$) x 0.940)]

Test Area	Effective		Condition	Description
	From	To		
T-12	***	***	All tests using UUXO Hardware	Multiply Average Top Ring Weight Loss by 0.849
				Multiply Average Cylinder Liner Wear by 0.566
				$\Delta Lead_{Final} = \exp[(\ln(\Delta Lead) \times 0.797)]$
				$\Delta Lead\ (250\text{-}300)_{Final} = \exp[(\ln(\Delta Lead\ 250\text{-}300) \times 0.700)]$
				$OC = \exp[(\ln(OC_{100\text{-}300}) \times 0.916)]$
	***	***	All tests using VXYPD Hardware	Multiply Average Top Ring Weight Loss by 0.846
				$ALW_{Final} = \exp[(\ln(ALW) \times 0.743)]$
				If $OC_{100\text{-}300} > 65.0$ $\Delta Lead_{Final} = \exp[(\ln(\Delta Lead) + (65.0 - OC_{100\text{-}300}) \times 0.03234]$ If $OC_{100\text{-}300} \leq 65.0$ $\Delta Lead_{Final} = \Delta Lead$
				If $OC_{100\text{-}300} > 65.0$ $\Delta Lead(250\text{-}300)_{Final} = \exp[\ln(\Delta Lead(250\text{-}300) + (65.0 - OC_{100\text{-}300}) \times 0.04089]$ If $OC_{100\text{-}300} \leq 65.0$ $\Delta Lead(250\text{-}300)_{Final} = \Delta Lead(250\text{-}300)$
				$OC = \exp[(\ln(OC_{100\text{-}300}) \times 0.926)]$
	***	***	All tests using WYZQ Hardware and Delo Coolant	Multiply Average Top Ring Weight Loss by 0.846
				$ALW_{Final} = \exp[(\ln(ALW) \times 0.743)]$
				If $OC_{100\text{-}300} > 65.0$ $\Delta Lead_{Final} = \exp[(\ln(\Delta Lead) + 0.4696 + (65.0 - OC_{100\text{-}300}) \times 0.03234]$ If $OC_{100\text{-}300} \leq 65.0$ $\Delta Lead_{Final} = \Delta Lead$
				If $OC_{100\text{-}300} > 65.0$ $\Delta Lead(250\text{-}300)_{Final} = \exp[\ln(\Delta Lead(250\text{-}300) + 0.6079 + (65.0 - OC_{100\text{-}300}) \times 0.04089]$ If $OC_{100\text{-}300} \leq 65.0$ $\Delta Lead(250\text{-}300)_{Final} = \Delta Lead(250\text{-}300)$
				$OC = \exp[(\ln(OC_{100\text{-}300}) \times 0.926)]$

Test Area	Effective		Condition	Description
	From	To		
T-13	***	***	All Tests on Batch B Cylinder and subsequent liners	Transformed Result + 0.857
RFWT	None		All Tests	None
EOAT	None		All Tests	None
T-12A	None		All Tests	None
DD13	None		All Tests	None

Test Area	Effective From	Effective To	Condition			Description
L-33-1	20200102	***	AAM K2XX & T1XX			Add +1 to rated areas 2 and 3. Do not exceed 10.
L37	20010612	***	V1L686/P4L626A Non-reference	MNP-Coated Ring	Canadian	Ridging add 0.9922
	20040825	***	V1L686/P4L626A Non-reference	MNP-Coated Pinion & Ring	Canadian	Ridging add 0.6065
	***	***	L247/T758A Non-reference	MNP-Coated Pinion	Canadian	Ridging add 0.5878, Pitting/Spalling add 0.7340
	***	20130514	V1L528/P4T883A Non-reference	Uncoated Pinion	Standard	Ridging add 0.3365, Rippling add 0.3365
					Canadian	Rippling add 0.7885
				MNP-Coated Pinion	Standard	Ridging add 0.3365
					Canadian	Ridging add 0.5878, Rippling add 0.5878
				MNP-Coated Ring	Canadian	Ridging add 0.3365
	20130515	***	V1L528/P4T883A Non-reference	Uncoated Pinion	Standard	Ridging add 0.3365, Rippling add 0.3365
					Canadian	Rippling add 0.7566
				MNP-Coated Pinion	Standard	Ridging add 0.3365
					Canadian	Ridging add 0.5878, Rippling add 0.5878
				MNP-Coated Ring	Canadian	Ridging add 0.3365
L-37-1	None	***	All Tests			None
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	20151001	***	All tests			Add 0.6 merits to ACV
HTCT			None			None
OSCT			None			None

Test Area	Effective From	Effective To	Condition	Description
D874	None		All Tests	None
D5800	None		All Tests	None

History of Industry Correction Factors
Appendix B

Test Area	Effective		Condition	Description
	From	To		
D5133 (GI)	None		All Tests	None
D6082	None		All Tests	None
D6417	None		All Tests	None
D6335 (TEOST)	None		All Tests	None
D7097 (MTEOS)	None		All Tests	None
D7528 (ROBO)	None		All Tests	None

APPENDIX C

HISTORY OF SEVERITY ADJUSTMENT (SA)
STANDARD DEVIATIONS

Test	Parameter	s	Effective Dates	
			From	To
Sequence IIIF	VIS80	0.0129546	20000610	20130513
		0.0000000	20130514	***
	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 IIIH	APV	0.327	20150701	20230911
		0.2376	20230912	***
	PVIS	0.4641	20150701	20230911
		0.4933	20230912	***
	WPD	0.47	20150701	20230911
		0.35	20230912	***
Sequence IIIHA	MRV Viscosity	0.4725	20150701	20230911
		0.4538	20230912	***
Sequence IIIHB	Phos. Retention	1.53	20150701	***
Sequence IVA	ACW	9.47	19980819	20010524
		12.50	20010525	20050630
		12.52	20050701	20120208
		15.72	20120209	20120710
		14.87	20120711	***
Sequence IVB	AVLI	0.2003	20171027	***

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	***
Sequence VH	AES	0.50	20170128	***
	RAC	0.2194	20170128	***
	AEV50	0.25	20170128	***
	APV50	0.53	20170128	***

[1] Transformation ln(OSCRNSLG + 1) adopted 20000525.

HISTORY OF SEVERITY ADJUSTMENT (SA)
STANDARD DEVIATIONS (Continued)

Test	Parameter	s	Effective Dates	
			From	To
Sequence IX	AVPIE	0.2856	20170421	20190627
	AVPIE	0.3775	20190628	***
Sequence X	CHST	0.17856	20170101	***
Sequence VIE	FEI1	0.29	20151213	20180313
	FEI2	0.25	20151213	20180313
	FEI1	0.235	20180314	***
	FEI2	0.281	20180314	***
Sequence VIF	FEI1	0.22	20151122	20241205
	FEI2	0.30	20151122	20241205
	FEI1	0.27	20241206	***
	FEI2	0.27	20241206	***
Sequence VIII	TBWL	3.40	19980829	19991116
		5.28	19991117	20020205
		4.80	20020206	20231202
		3.38	20241203	***
	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[1]	14.6	19930314	20150331
		0.488165	20150401	***
	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	--	--

[1] Transformation ln(TGF+1) adopted 20150401

HISTORY OF SEVERITY ADJUSTMENT (SA)
STANDARD DEVIATIONS (Continued)

Test	Parameter	s	Effective Dates	
			From	To
C13 Aeration	AAVE4050	0.285	20141101	20180201
		0.2774	20180202	***
ISB	Camshaft Wear	8.7	20171129	20200903
		8.5	20200904	***
	Tappet Wt. Loss	14.8	20171129	***
ISM	X-Head Wear	None	--	--
	OFDP	None	--	--
	Average Sludge	None	--	--
	Adj. Screw Wear	None	--	--
T-8	Vis. Inc. @ 3.8%	1.19	19940401	19960930
		0.93	19961001	19990131
		0.90	19990201	20070524
		0.00	20070525	20110916
		0.56	20110917	***
T-8E	Rel. Vis. @ 4.8% 50% DIN Shear	0.26	19970127	20070524
		0.00	20070525	20110916
		0.08	20110917	***
	Rel. Vis. @ 4.8% 100% DIN Shear	0.27	20020306	20070524
		0.00	20070525	20110916
		0.09	20110917	***
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	20200729
	MRV Viscosity	1117	20200730	***

HISTORY OF SEVERITY ADJUSTMENT (SA)
STANDARD DEVIATIONS (Continued)

Test	Parameter	s	Effective Dates	
			From	To
T12	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	***
T13	IRPH	12.4	20141001	20160127
	%KV40[1]	1.212	20141001	20160127
	IRPH	11.1	20160128	***
	%KV40[1]	0.929	20160128	***
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	***
DD13	Hours to Scuff	None	20150101	***

1 SQRT Transformation adopted 20151019

HISTORY OF SEVERITY ADJUSTMENT (SA)
STANDARD DEVIATIONS (Continued

Test	Parameter	s	Effective Dates	
			From	To
L-33-1	Rust	0.350	20020611	***
L-37 Uncoated	Pinion Ridging	0.666	19000101	***
	Pinion Rippling	0.557	19000101	***
	Pinion Spitting	0.847	19000101	***
	Pinion Wear	0.713	19000101	***
L-37 MNP-Coated	Pinion Ridging	1.430	19000101	***
	Pinion Rippling	0.476	19000101	***
	Pinion Spitting	0.579	19000101	***
	Pinion Wear	0.519	19000101	***
L-37-1 Uncoated	Pinion Ridging	0.666	20130716	***
	Pinion Rippling	0.557	20130716	***
	Pinion Spitting	0.847	20130716	***
	Pinion Wear	0.713	20130716	***
L-42	% Scoring	None	--	--
L-60-1	Vis. Inc.	7.659	19000101	***
	Pentane	0.413	19000101	***
	Carbon/Varnish	0.249	19000101	***
	Sludge	0.511	19000101	***
	Toluene	0.106	19000101	***
HTCT	Cycles	None	--	--
OSCT	Elongation	None	--	--
	Shore Hardness	None	--	--
	Volume Change	None	--	--

Test	Parameter	s	Effective Dates	
			From	To
D874	None			
D5800	Sample Evaporation Loss	0.73	20131019	***
D5133 (GI)	None			
D6082	None			
D6417	None			
D6335 (TEOST)	None			
D7097 (MTEOS)	None			

APPENDIX D

REFERENCE OIL VISCOSITY GRADES

Oil	SAE Viscosity Grade	Date Received[1]
52	15W-40	19950830
55	10W-30	19950918
58	5W-30	19981001
62	10W-40	19960304
66	15W-40	20020418
75	5W-30	20101007
90	15W-40	20050922
91	5W-20	20060814
112	90	19940221
112-1	90	19940621
112-2	90	19951127
113	90	20021113
114	90	19940222
114-1	90	19970617
115	80W-90	19971103
116	80W-90	20050415
116	80W-90	20050418
117	80W-90	20130819
121	90	19960329
121-1	90	19970303
121-2	90	19990930
123	90	19950116
123-1	90	19991029
123-2	90	20010723
127	80W-90	19930819
128	80W-90	19930820
128-1	80W-90	19960209
128-2	80W-90	20010725
129	90	19930823
131	85W-140	19850924
131-1	85W-140	19860318
131-2	85W-140	19880126
131-3	85W-140	19911025
131-4	85W-140	19950315
133	85W-140	19981013
134	80W-90	20070926

REFERENCE OIL VISCOSITY GRADES

Oil	SAE Viscosity Grade	Date Received[1]
134-1	80W-90	20151106
143	80W-90	19891009
148	80W-90	19930713
148-1	80W-90	20010927
150	80W-90	19930603
150-1	80W-90	19940430
150-2	80W-90	19950510
151	80W-90	19930520
151-1	80W-90	19940503
151-2	80W-90	19950727
151-3	80W-90	19990929
152	75W-90	20040223
152-1	75W-90	20040927
152-2	75W-90	20090915
152-2A	75W-90	2009915
152-2B	75W-90	20090821
152-3	75W-90	20110627
153	75W-90	20040213
153-1	75W-90	20040913
154	90	20050905
155	90	20050510
155-1	90	20101123
155-2	90	20200708
160	80W-90	19920925
160-1	80W-90	19960328
161	75W-90	19930104
161-1	75W-90	19951003
162	80W-90	19921015
168	80W-90	20050721
169	75W-90	20100602
170	80W-90	20150819
171	80W-90	20170331
221	0W-16	20151202
222	10W-30	20151215
224	5W-30	20180524
270	5W-30	20150708
271	5W-30	20151009
433	5W-30	20000713
433-1	5W-30	20000928

REFERENCE OIL VISCOSITY GRADES

Oil	SAE Viscosity Grade	Date Received[1]
433-2	5W-30	20130306
434	5W-30	20030303
434-1	5W-30	20080512
434-2	5W-30	20140228
434-3	5W-30	20170718
435	5W-20	20030313
435-1	5W-20	20080904
435-2	5W-20	20100902
436	5W-20	20141105
438	5W-20	20030302
438-1 (538-1)	5W-20	20070212
438-2	5W-20	20170922
538	5W-20	20010622
538-1	5W-20	20070212
539	10W-30	20020308
540 (GF5A)	5W-20	20090106
541 (GF5D)	10W-30	20081211
541-1	10W-30	20110405
542 (GF5X)	0W-20	20081215
542-1	0W-20	20130109
542-2	0W-20	20141007
542-3	0W-20	20151006
542-4	0W-20	20181212
543	0W-16	20150925
544	5W-30	20151007
704	10W-30	19910131
704-1	10W-30	19920114
809-1	15W-40	19910402
810-1	15W-40	19890920
810-2	15W-40	19921214
811-1	15W-40	19900419
811-2	15W-40	19950921
820 (PC-9A)	15W-40	20001016
820-1	15W-40	20011005
820-2	15W-40	20011130
820-3	15W-40	20060828
821 (PC10E)	15W-40	20050307
821-1	15W-40	20071105
821-2	15W-40	20090327
821-3	15W-40	20120807
821-4	15W-40	20131220
822	15W-40	20120828
822-1	15W-40	20130125

REFERENCE OIL VISCOSITY GRADES

Oil	SAE Viscosity Grade	Date Received[1]
822-2	15W-40	20130722
823 (PC11A)	10W30	20150521
830 (PC-9E)	15W-40	20001109
830-1	15W-40	20020107
830-2	15W-40	20020401
830-3	15W-40	20161221
831 (PC10B)	15W-40	20050330
831-1	15W-40	20070710
831-2	15W-40	20111128
831-3	15W-40	20150317
831-4	15W-40	20170217
832 (PC11G)	15W-40	20150521
832-1	15W-40	20180524
833 (PC11K)	15W-40	20150325
833-1	15W-40	20170619
864 (X)	5W-30	20160520
864-1	5W-30	20160705
866 (C)	10W-30	20160609
873	40	19930728
873-1	40	19940214
873-2	40	20020313
925	5W-30	19870123
925-1	5W-30	19880216
925-2	5W-30	19900614
925-3	5W-30	19930608
931	0W-20	20200303
940	5W-30	20120425
940-1	5W-30	20180605
1004-2	15W-40	19941216
1004-3	15W-40	19960508
1005	15W-40	19960229
1005-1	15W-40	19980121
1005-2	15W-40	20030926
1005-3	15W-40	20090928
1005-4	15W-40	20120731
1005-5	15W-40	20150116
1006	5W-30	19961014
1006-1	5W-30	20000907
1006-2	5W-30	20001026
1007	5W-30	19980424
1008	5W-30	19980601
1008-1	5W-30	20020318
1009	5W-30	20020307
1009-1	5W-30	20170530
1010	5W-20	20100824

REFERENCE OIL VISCOSITY GRADES

Oil	SAE Viscosity Grade	Date Received[1]
1010-1	5W-20	20141016
1011	0W-16	20150413
1011-1	0W-16	20190924
1012	5W-20	20170126
FOAMB18	5W-20	20180111
GIA17	10W-30	20171220
VOLC12	5W-30	20130214
VOLD12	0W-20	20130218
VOLE12	5W-20	20130218

[1] Date received into TMC warehouse.

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	±0.000 (Continuous)
IIIGA	Laboratory	All	±0.550
IIIGB	Laboratory	All	±0.550
IIIH	Stand	All	±0.000 (Continuous)
IIIHA	Stand	All	±0.000 (Continuous)
IIIHB	Stand	All	±0.000 (Continuous)
IVA	Laboratory	All	±0.756
IVB	Stand	All	±0.000 (Continuous)
VG	Laboratory	All	±0.653
VH	Laboratory	All	±0.000 (Continuous)
IX	Stand/engine	All	±0.000 (Continuous)
IX Aged	None	None	None
X	Stand	All	±0.000 (Continuous
VIE	Stand	All	±0.000 (Continuous)
VIF	Stand	All	±2.0
			±2.8
VIII	Laboratory	TBWL	±0.600
1M-PC	Laboratory	All	±0.653
1K	Laboratory	WTD,TGF,TLHC	±0.653
1N	Laboratory	WTD,TGF,TLHC	±0.653
1P	Laboratory	All	±0.653
1R	Laboratory	All	±0.653
C13	None	None	None
COAT	Stand	All	±0.000 (Continuous)
ISB	Stand	All	±0.000 (Continuous)
ISM	None	None	None
T-8/T-8E	Laboratory	All	±0.653
T-11	Laboratory	All	±0.653
T-12	Laboratory	All	±0.653
T-13	Laboratory	All	±0.000 (Continuous)

Test Type	Alarm Level	Parameter(s)	Alarm Limit
RFWT	Laboratory	All	±0.600;
EOAT	Stand	All	±0.000 (Continuous)
DD13	Laboratory	None	None
L-33-1	Stand	All	±0.823
L-37	Stand	All	±0.653
L-37-1	Stand	All	±0.653
L-42	None	None	None
L-60-1	Stand	All	±0.653
HTCT	None	None	None
OSCT	None	None	None
D874	None	None	None
D5800	Instrument	All	±0.000 (Continuous)
D5133 (GI)	None	None	None
D6082	None	None	None
D6335 (TEOST)	None	None	None
D6417	None	None	None
D7097 (MTEOS)	None	None	None
D7528 (ROBO)	None	None	None

Severity Adjustment Calculation Procedure (except Sequence VIE, refer to Sequence VIE section):

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.

APPENDIX H
TEST RUN NUMBERING

TESTTYPE	TESTNUM	Component 1	Component 2	Component 3	Component 4	Component 5	Rerun Designation
IIIF	STAND--STRUN-LABRUN	STAND	STRUN	LABRUN			
		Alphanumeric Stand Name	Incremental count of runs on Stand	Incremental count of runs in lab			Alphabetic letter appended to LABRUN
IIIG	STAND--STRUN-LABRUN	STAND	STRUN	LABRUN			
		Alphanumeric Stand Name	Incremental count of runs on Stand	Incremental count of runs in lab			Alphabetic letter appended to LABRUN
IIIH	STAND--STRUN-TOTSRUN	STAND	STRUN	TOTSRUN			
		Alphanumeric Stand Name	Incremental count of runs since reference	Incremental count of runs on Stand			Alphabetic letter appended to TOTSRUN
IVA	STAND--STRUN-TOTSRUN	STAND	STRUN	TOTSRUN			
		Alphanumeric Stand Name	Incremental count of runs since reference	Incremental count of runs on Stand			Alphabetic letter appended to TOTSRUN
IVB	STAND--CALCOUNT-TOTSRUN	STAND	CALCOUNT	TOTSRUN			
		Alphanumeric Stand Name	Incremental count of runs since reference	Incremental count of runs on Stand			Alphabetic letter appended to TOTSRUN
IX	STAND-STRUN-ENGNO-ENRUN	STAND	STRUN	ENGNO	ENRUN		
		Alphanumeric Stand Name	Incremental count of runs on Stand	Alphanumeric Engine Name	Incremental count of runs on Engine		Increment STRUN and ENRUN
X	STAND--CALCOUNT-TOTSRUN	STAND	CALCOUNT	TOTSRUN			
		Alphanumeric Stand Name	Incremental count of runs since reference	Incremental count of runs on Stand			Alphabetic letter appended to TOTSRUN

APPENDIX H
TEST RUN NUMBERING

TESTTYPE	TESTNUM	Component 1	Component 2	Component 3	Component 4	Component 5	Rerun Designation
IX AGED	STAND--CALCOUNT-TOTSRUN	STAND	CALCOUNT	TOTSRUN			
		Alphanumeric Stand Name	Incremental count of runs since reference	Incremental count of runs on Stand			Alphabetic letter appended to TOTSRUN
VH	STAND--CALCOUNT-TOTSRUN	STAND	CALCOUNT	TOTSRUN			
		Alphanumeric Stand Name	Incremental count of runs since reference	Incremental count of runs on Stand			Alphabetic letter appended to TOTSRUN
VIE	STAND-STRUN-ENGNO-ENRUN	STAND	STRUN	ENGNO	ENRUN		
		Alphanumeric Stand Name	Incremental count of runs on Stand	Alphanumeric Engine Name	Incremental count of runs on Engine		Alphabetic letter appended to ENRUN
VIF	STAND-STRUN-ENGNO-ENRUN	STAND	STRUN	ENGNO	ENRUN		
		Alphanumeric Stand Name	Incremental count of runs on Stand	Alphanumeric Engine Name	Incremental count of runs on Engine		Alphabetic letter appended to ENRUN
VIII	STAND-ENGINE-ENRUNSR-TOTENRUN	STAND	ENGINE	ENRUNSR	TOTENRUN		
		Alphanumeric Stand Name	Alphanumeric Engine Name	Incremental count of runs since reference	Incremental count of runs on Engine		Alphabetic letter appended to TOTENRUN
1K/1N	STAND-ENRUN	STAND	ENRUN				
		Alphanumeric Stand Name	Incremental count of test runs				Alphabetic letter appended to ENRUN
1MPC	STAND-ENRUN	STAND	ENRUN				
		Alphanumeric Stand Name	Incremental count of test runs				Alphabetic letter appended to ENRUN

APPENDIX H
TEST RUN NUMBERING

TESTTYPE	TESTNUM	Component 1	Component 2	Component 3	Component 4	Component 5	Rerun Designation
1P	STAND-ENRUN	STAND	ENRUN				
		Alphanumeric Stand Name	Incremental count of test runs				Alphabetic letter appended to ENRUN
1R	STAND-ENRUN	STAND	ENRUN				
		Alphanumeric Stand Name	Incremental count of test runs				Alphabetic letter appended to ENRUN
C13	STAND-STRUN	STAND	STRUN				
		Alphanumeric Stand Name	Incremental count of runs on Stand				Alphabetic letter appended to STRUN
COAT	STAND-STRUN-ENGINE-ENRUN	STAND	STRUN	ENGINE	ENRUN		
		Alphanumeric Stand Name	Incremental count of runs on Stand	Engine Serial Number	Incremental count of runs on Engine		Alphabetic letter appended to STRUN
ISB	STAND-STRUN-ENGINE-ENHOURS	STAND	STRUN	ENGINE	ENHOURS		
		Alphanumeric Stand Name	Incremental count of runs on Stand	Engine Serial Number	Number of test hours on engine block at start of test		Alphabetic letter appended to STRUN
ISM	STAND-ENGINE-STRUN	STAND	ENGINE	STRUN			
		Alphanumeric Stand Name	Engine Serial Number	Incremental count of runs on Stand			Alphabetic letter appended to STRUN
DD13	STAND-STRUN-ENGINE-ENHOURS-ENKITID	STAND	STRUN	ENGINE	ENHOURS	ENKITID	
		Alphanumeric Stand Name	Incremental count of runs on Stand	Engine Serial Number	Number of test hours on engine block at start of test	TEI Engine Kit ID number	Alphabetic letter appended to STRUN

APPENDIX H
TEST RUN NUMBERING

TESTTYPE	TESTNUM	Component 1	Component 2	Component 3	Component 4	Component 5	Rerun Designation
EOAT	STAND-STRUN-ENGINE-ENRUN	STAND	STRUN	ENGINE	ENRUN		
		Alphanumeric Stand Name	Incremental count of runs on Stand	Engine Serial Number	Number of test hours on engine block at start of test		not defined in procedure
T8	STAND-STRUN-ENGINE-ENHOURS	STAND	STRUN	ENGINE	ENHOURS		
		Alphanumeric Stand Name	Incremental count of runs on Stand	Engine Serial Number	Number of test hours on engine block since last reference		Alphabetic letter appended to STRUN
T11	STAND-STRUN-ENGINE-ENHOURS	STAND	STRUN	ENGINE	ENHOURS		
		Alphanumeric Stand Name	Incremental count of runs on Stand	Engine Serial Number	Number of accumulated test hours since last reference test		Alphabetic letter appended to STRUN
T12/T12A	STAND-STRUN-ENGINE-ENHOURS	STAND	STRUN	ENGINE	ENHOURS		
		Alphanumeric Stand Name	Incremental count of runs on Stand	Engine Serial Number	Number of accumulated test hours since last reference test		Alphabetic letter appended to STRUN
T13	STAND-STRUN-ENGINE-ENKITID	STAND	STRUN	ENGINE	ENKITID		
		Alphanumeric Stand Name	Incremental count of runs on Stand	Engine Serial Number	TEI Engine Kit ID number		Alphabetic letter appended to STRUN
RFWT	STAND-STRUN-ENGINE-ENRUN	STAND	STRUN	ENGINE	ENRUN		
		Alphanumeric Stand Name	Incremental count of runs on Stand	Engine Kit Number	Number of runs on ENGINE		Alphabetic letter appended to STRUN

APPENDIX H
TEST RUN NUMBERING

TESTTYPE	TESTNUM	Component 1	Component 2	Component 3	Component 4	Component 5	Rerun Designation
L331	SBOXNUM-SBOXRUN	SBOXNUM	SBOXRUN				
		Alphanumeric Stand Name	Incremetal count of runs on Stand				None
L37	STAND-STRUN	STAND	STRUN				
		Alphanumeric Stand Name	Incremetal count of runs on Stand				None
L371	STAND-STRUN	STAND	STRUN				
		Alphanumeric Stand Name	Incremetal count of runs on Stand				None
L42	STAND-STRUN	STAND	STRUN				
		Alphanumeric Stand Name	Incremetal count of runs on Stand				None
L601	STAND-STRUN	STAND	STRUN				
		Alphanumeric Stand Name	Incremetal count of runs on Stand				None
HTCT	STAND-STRUN	STAND	STRUN				
		Alphanumeric Stand Name	Incremetal count of runs on Stand				None
OSCT	None						
							None
EOEC	None						
							None
LDEOC	None						
							None

APPENDIX H
TEST RUN NUMBERING

TESTTYPE	TESTNUM	Component 1	Component 2	Component 3	Component 4	Component 5	Rerun Designation
BRT	SHKTBLID-TESTRUNNO	SHKTBLID	TESTRUNNO				
		Alphanumeric Stand Name	Incremetal count of runs on Stand				None
CBT	BTHNO-BTHRUNNO	BTHNO	BTHRUNNO				
		Alphanumeric Stand Name	Incremetal count of runs on Stand				None
HTCBT	BTHNO-BTHRUNNO	BTHNO	BTHRUNNO				
		Alphanumeric Stand Name	Incremetal count of runs on Stand				None
EOWT	TSTNO	TSTNO					
		Test number					None
EOFT	TSTNO	TSTNO					
		Test number					None
D5800 (NOACK)	Refer to appropriate section for run numbering details						
D6082	Refer to appropriate section for run numbering details						
D6335 (TEOST)	Refer to appropriate section for run numbering details						
D6417	Refer to appropriate section for run numbering details						
D7097 (MTEOS)	Refer to appropriate section for run numbering details						
D7828 (ROBO)	Refer to appropriate section for run numbering details						

APPENDIX H
TEST RUN NUMBERING