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.

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.

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.

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.

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