14. 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
544	1.30	0.214
1010-1	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
544	1.41	0.256
1010-1	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	±2.5
	Repeatability Check	N/A	±2.8
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.

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	±2.0
	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: $SA = (-W_i) \times (0.22)$
FEI2: $SA = (-W_i) \times (0.30)$

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

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

A. Reference Oils and Parameters

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

VISCOSITY INCREASE @ 3.8% SOOT
Unit of Measure: cSt
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

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	***	8.12	0.38
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	***	9.25	0.22

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.

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
544[4,5]	43	03-14-18	***	1.30	0.214	1.41	0.256
1010-1[4,5]	39	03-14-18	***	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.

History of Industry Correction Factors
Appendix B

Test Area	Effective From	Effective To	Condition	Correction
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	None		All Tests	None

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

Test	Parameter	s	Effective Dates	
			From	To
Sequence IX	AVPIE	0.2856	20170421	***
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	***
	FEI2	0.30	20151122	***
Sequence VIII	TBWL	3.40	19980829	19991116
		5.28	19991117	20020205
		4.80	20020206	***
	10hr. Stripped Vis.	None	--	--
1M-PC	WTD	50.5	19930914	***
	TGF	16.1	19930914	***
1K	WDK	35.6	19900506	***
	TGF	15.7	19900506	***
	TLHC	1.1	19900506	***
	OC	None	--	--
1N	WDN	27.1	19930314	***
	TGF[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	--	--
C13 Aeration	AOA40-50	0.285	20141101	***

1 Transformation ln(TGF+1) adopted 20150401

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	±0.600
VG	Laboratory	All	±0.653
VH	Laboratory	All	±0.000 (Continuous)
IX	Stand	All	±0.000 (Continuous)
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
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)
RFWT	Laboratory	All	±0.600