– 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:

$$\text{AVPIE SA} = (-Z_i) \times (0.3775)$$

$$\text{MAXPIE SA} = \text{AVPIE SA}$$

- 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.

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. <u>Acceptance Criteria</u>

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.

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 = ($-W_i$) x (0.22)
FEI2: SA = ($-W_i$) x (0.30)

- 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.

21. 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

ISM Reference Oil Targets											
		Effective Dates		X-Head Wear @ 3.9% Soot		OFDP[1]		Average Sludge		Injector Adj. Screw Wear @ 3.9% Soot	
Oil	n	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

History of Industry Correction Factors
Appendix B

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 and subsequent batch 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
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)]
				ΔLead $(250\text{-}300)_{Final}$ = exp[(ln(ΔLead 250-300) x 0.956)]
				OC = exp[(ln($OC_{100\text{-}300}$) x 0.961)]