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 start an additional test on the stand or engine-stand combination (if appropriate) that triggered the alarm. Do not update severity adjustments until after the Excessive Influence analysis is completed.

16. 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
833	11.94	0.285

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 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: $SA = -Z_i \times (0.285)$

- 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. 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.

IR Oxidation Peak Height
Unit of Measure: absorbance / cm

Reference Oil	Mean	Standard Deviation
823	142.7	12.4

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

Reference Oil	Mean	Standard Deviation
823	9.303	1.212

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
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.

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	To[1]	$\overline{X}$	s	$\overline{X}$	s
PC11A	6	10-01-2014	***	142.7	12.4	9.303	1.212
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	***	142.7	12.4	9.303	1.212

1 *** = currently in effect
2 SQRT Transformation adopted 20151019

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

Test	Parameter	s	Effective Dates	
			From	To
T-8	Vis. Inc. @ 3.8%	1.19	19940401	19960930
	Vis. Inc. @ 3.8%	0.93	19961001	19990131
	Vis. Inc. @ 3.8%	0.90	19990201	20070524
	Vis. Inc. @ 3.8%	0.00	20070525	20110916
	Vis. Inc. @ 3.8%	0.56	20110917	***
T-8E	Rel. Vis. @ 4.8% 50% DIN Shear	0.26	19970127	20070524
	Rel. Vis. @ 4.8% 50% DIN Shear	0.00	20070525	20110916
	Rel. Vis. @ 4.8% 50% DIN Shear	0.08	20110917	***
	Rel. Vis. @ 4.8% 100% DIN Shear	0.27	20020306	20070524
	Rel. Vis. @ 4.8% 100% DIN Shear	0.00	20070525	20110916
	Rel. Vis. @ 4.8% 100% DIN Shear	0.09	20110917	***
T-10A	MRV Viscosity	511	20001201	20020115
		643	20020116	20020924
		496	20020925	20030121
		497	20030122	***
T-11	Soot@4.0 cSt Vis	0.23	20050528	20130702
	Soot@12.0 cSt Vis	0.21	20030308	20130702
	Soot@15.0 cSt Vis	0.26	20050528	20130702
	MRV Viscosity	1097	20030308	20130702
	Soot@4.0 cSt Vis	0.20	20130703	***
	Soot@12.0 cSt Vis	0.50	20130703	***
	Soot@15.0 cSt Vis	0.61	20130703	***
	MRV Viscosity	584	20130703	***
T-12	Cyl. Liner Wear	1.6	20050219	***
	Top Ring Wt. Loss	24.9	20050219	***
	Oil Consumption	0.0610	20050219	***
	ΔPB @ EOT	0.2880	20050219	***
	ΔPB 250-300 h	0.3630	20050219	***
	Cyl. Liner Wear	1.6	20050219	***
	Top Ring Wt. Loss	24.9	20050219	***
	Oil Consumption	0.0610	20050219	***
	ΔPB @ EOT	0.2880	20050219	***
	ΔPB 250-300 h	0.3630	20050219	***
T13	IRPH	12.4	20141001	***
	%KV40[1]	1.212	20141001	***

1 SQRT Transformation adopted 20151019