

## 19. 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<sub>i</sub> 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<sub>i</sub> 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.

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:  $SA = -Z_i \times (0.2774)$

C13 Aeration Reference Oil Targets					
Oil	n	Effective Dates		40 - 50 Hour Average Aeration %	
		From	To <sup>1</sup>	$\bar{X}$	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

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	***
	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 <sup>1</sup>	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	--	--
	OCA	None	--	--
	R2TC	None	--	--
C13 Aeration	AAVE4050	0.285	20141101	20180201
		0.2774	20180202	***

<sup>1</sup> Transformation  $\ln(\text{TGF}+1)$  adopted 20150401

32. 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.
Gleason 04-2014	NONLUBRITED	134	3.8	1.2
		152-2	9.3	0.7
		155-1	9.6	0.5
	LUBRITED	134	6.1	2.4
		152-2	9.7	0.5
		155-1	9.3	1.0

RIPPLING  
Unit of Measure: Merits

Pinion Batch	Hardware	Reference Oil	Mean	Standard Dev.
Gleason 04-2014	NONLUBRITED	134	7.8	1.2
		152-2	8.9	1.6
		155-1	9.6	0.5
	LUBRITED	134	7.4	1.6
		152-2	9.3	0.5
		155-1	8.7	0.7

PITTING/SPALLING  
Unit of Measure: Merits

Pinion Batch	Hardware	Reference Oil	Mean	Standard Dev.
Gleason 04-2014	NONLUBRITED	134	7.7	1.9
		152-2	9.9	0.0
		155-1	9.9	0.0
	LUBRITED	134	9.9	0.1
		152-2	9.7	0.6
		155-1	9.9	0.0

WEAR  
Unit of Measure: Merits

Pinion Batch	Hardware	Reference Oil	Mean	Standard Dev.
Gleason 04-2014	NONLUBRITED	134	4.8	1.2
		152-2	7.8	0.9
		155-1	7.9	0.7
	LUBRITED	134	6.8	0.9
		152-2	8.2	0.7
		155-1	7.9	0.8

SCORING  
Non-lubrited & Lubrited 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

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:

Non-lubrited 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:  $SA = (-Z_i) \times (0.713)$

Lubrited Test Hardware:

Ridging:  $SA = (-Z_i) \times (n/a)$

Rippling:  $SA = (-Z_i) \times (n/a)$

Pitting/Spalling:  $SA = (-Z_i) \times (n/a)$

Wear:  $SA = (-Z_i) \times (n/a)$

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, lubrited 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 potential problem.

L-37-1 Reference Oil Targets													
Hardware	Pinion Batch	Oil	n	From <sup>1</sup>	To	Ridging		Rippling		Spitting		Wear	
						$\bar{X}$	s	$\bar{X}$	s	$\bar{X}$	s	$\bar{X}$	s
NONLUBRICATED	Gleason 04-2014	134	13	20130716	***	3.8	1.2	7.8	1.2	7.7	1.9	4.8	1.2
		152-2	15	20130716	***	9.3	0.7	8.9	1.6	9.9	0.0	7.8	0.9
		155-1	9	20130716	***	9.6	0.5	9.6	0.5	9.9	0.0	7.9	0.7
LUBRICATED	Gleason 04-2014	134	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	9	20191001	***	9.3	1.0	8.7	0.7	9.9	0.0	7.9	0.8

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

2 \*\*\* = currently in effect.



42. 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 1  
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	95% band in	95% Bands	95% Bands
					mPa·s Min <sup>1</sup>	mPa·s Max <sup>1</sup>	Min (ln)	Max (ln)
434-1	13	10.6599	42,612	0.1672	30,706	59,136	10.3322	10.9876
434-2	36	<sup>2</sup> 10.9284	<sup>2</sup> 55,737	0.1551	<sup>2</sup> 41,126	<sup>2</sup> 76,008	<sup>2</sup> 10.6244	<sup>2</sup> 11.2386
434-3	13	<sup>2</sup> 10.8411	<sup>2</sup> 51,078	0.1342	<sup>2</sup> 39,265	<sup>2</sup> 66,443	<sup>2</sup> 10.5781	<sup>2</sup> 11.1041
435	15	11.4895	97,685	0.2932	<sup>3</sup> 60,000	173,546	<sup>3</sup> 11.0021	12.0642
435-1	22	11.0416	62,420	0.20295	<sup>4</sup> 44570	92910	<sup>4</sup> 10.7048	11.4394
438	14	10.2676	28,785	0.2037	19,308	42,912	9.8683	10.6669
438-2	19	<sup>2</sup> 10.5404	<sup>2</sup> 37813	0.2596	<sup>2</sup> 22,734	<sup>2</sup> 62,894	<sup>2</sup> 10.0316	<sup>2</sup> 11.0492

<sup>1</sup> 95% bands in mPa·s are listed for information purposes only, the transformed values will be used to judge acceptance in all cases.

<sup>2</sup> A bias adjustment has been applied to the mean of reference oils 434-2, 434-3 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.

<sup>3</sup> 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.

<sup>4</sup>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.

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 Test Stands

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.

#### 4. 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%

#### 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 B.1.b through B.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 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.

D6082 High Temperature Foam Test Reference Oil Targets							
Oil	n	Effective Dates		Foam Tendency		Foam Stability	
		From <sup>1</sup>	To <sup>2</sup>	$\bar{X}$	s	$\bar{X}$	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

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

D6335 (TEOST) Thermo-Oxidation Engine Oil Simulation Test Reference Oil Targets					
Oil	N	Effective Dates		Total Deposits	
		From <sup>1</sup>	To <sup>2</sup>	$\bar{X}$	s
71	27	19900101	20130414	51.79	4.79
71-1 <sup>3</sup>		20090113	20130414	51.79	4.79
72	27	19000101	20130414	26.72	3.46
72-1 <sup>4</sup>		20090113	20130414	26.72	3.46
75	14	20110108	20130414	55.16	5.68
75	30	20130415	***	53.66	6.56
75-1	16	20190404	***	56.9	5.02
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					
Oil	n	Effective Dates		Area % Volatized	
		From <sup>1</sup>	To <sup>2</sup>	$\bar{X}$	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					
Oil	n	Effective Dates		Total Deposits	
		From <sup>1</sup>	To <sup>2</sup>	$\bar{X}$	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					
Oil	N	Effective Dates		LN(EOT MRV)	
		From <sup>1</sup>	To <sup>2</sup>	$\bar{X}$	s
434-1	13	20080801	***	10.6599	0.1672
434-2	5	20170713	20180727	10.941	0.1672
	36	20180728	***	10.9284	0.1551
434-3	13	20191101	***	10.8411	0.1342
435	15	20080801	20110928	11.4895	0.2932
435-1	22	20100408	***	11.0416	0.20295
438	14	20080801	***	10.2676	0.2037
438-2	10	20190221	20191031	10.4421	0.2322
	19	20191101	***	10.5404	0.2596

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

2 \*\*\* = currently in effect.