21. ISB LTMS Requirements

The following are the specific ISB calibration test requirements.

A. Reference Oils and Parameters

The critical parameters are Average Cam Shaft Wear and Average Tappet Weight Loss. The reference oils required for test stand and test laboratory calibration are reference oils accepted by the ASTM Cummins Test Surveillance Panel. The mean and standard deviation for the current reference oils for each critical parameter are presented below.

AVERAGE CAM SHAFT WEAR
Unit of Measure: LN(ACSW)

Reference Oil	Mean	Standard Deviation
831-3	3.7495	0.2302
831-4	3.7495	0.2302
835	3.9338	0.2302

AVERAGE TAPPET WEIGHT LOSS
Unit of Measure: SQRT(ATWL)

Reference Oil	Mean	Standard Deviation
831-3	9.8590	1.1755
831-4	9.8590	1.1755
835	9.7057	1.1755

B. Acceptance Criteria

1. New Test Stand

- A minimum of two (2) operationally valid calibration tests with no level 3 e_i or Level 2 Z_i alarms after the second operationally valid test must be conducted in a new stand 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.

2. Existing Test Stand

- The test stand must have been previously accepted into the system by meeting LTMS calibration requirements.
- One operationally valid test with no level 3 e_i or level 2 Z_i alarms must be conducted on any approved reference oil.
- Following the necessary tests, check the status of the control charts and follow the prescribed actions.

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. Evaluate any subsequent test(s) using Level 3 e_i limits.

Exceed Stand EWMA of Standardized Test Result (Z_i)

Level 2:

– Conduct one additional reference test in the stand that triggered the alarm. The 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 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 stand severity adjustment (SA). Calculate the stand SA as follows and confirm the calculation with the TMC:

Average Cam Shaft Wear: $SA = (-Z_i) \times (0.2032)$
Average Tappet Weight Loss: $SA = (-Z_i) \times (1.1755)$

- 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.

35. 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.	Acceptance Bands
Gleason 04-2014, 06-2018, 2019/20	UNCOATED	134/134-1	4.1	0.9	-
		152-2	9.0	0.8	-
		155-1/155-2	9.5	0.5	-
Gleason 04-2014	MNP-COATED	134/134-1	6.1	2.4	-
		152-2	9.7	0.5	-
		155-1/155-2	9.3	1.0	-
Gleason 04-2021		134/134-1	-	-	4 - 6
		152-2	-	-	8 – 10
		155-1/155-2	-	-	8 – 10

RIPPLING
Unit of Measure: Merits

Pinion Batch	Hardware	Reference Oil	Mean	Standard Dev.	Acceptance Bands
Gleason 04-2014, 06-2018, 2019/20	UNCOATED	134/134-1	7.4	1.4	-
		152-2	8.3	1.2	-
		155-1/155-2	8.6	1.1	-
Gleason 04-2014	MNP-COATED	134/134-1	7.4	1.6	-
		152-2	9.3	0.5	-
		155-1/155-2	8.7	0.7	-
Gleason 04-2021		134/134-1	-	-	5 - 8
		152-2	-	-	7 – 9
		155-1/155-2	-	-	7 – 9

PITTING/SPALLING
Unit of Measure: Merits

Pinion Batch	Hardware	Reference Oil	Mean	Standard Dev.	Acceptance Bands
Gleason 04-2014, 06-2018, 2019/20	UNCOATED	134/134-1	7.9	2.0	-
		152-2	9.9	0.1	-
		155-1/155-2	9.9	0.0	-
Gleason 04-2014	MNP-COATED	134/134-1	9.9	0.1	-
		152-2	9.7	0.6	-
		155-1/155-2	9.9	0.0	-
Gleason 04-2021		134/134-1	-	-	9.8 - 9.9
		152-2	-	-	9.9 – 10.0
		155-1/155-2	-	-	9.8 – 10.0

WEAR
Unit of Measure: Merits

Pinion Batch	Hardware	Reference Oil	Mean	Standard Dev.	Acceptance Bands
Gleason 04-2014, 06-2018, 2019/20	UNCOATED	134/134-1	5.3	0.9	-
		152-2	7.6	0.7	-
		155-1/155-2	7.5	0.7	-
Gleason 04-2014	MNP-COATED	134/134-1	6.8	0.9	-
		152-2	8.2	0.7	-
		155-1/155-2	7.9	0.8	-
Gleason 04-2021		134/134-1	-	-	6 - 7
		152-2	-	-	7 – 8
		155-1/155-2	-	-	7 – 8

SCORING
Uncoated & MNP-coated 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

- A minimum of three (3) operationally valid calibration tests must be conducted with results falling within the acceptance bands. Two of the three tests are to be conducted on either

37. L-60-1 LTMS Requirements

The following are the specific L-60-1 calibration test requirements.

A. Reference Oils and Parameters

The critical parameters are Viscosity Increase, Pentane Insolubles, Average Carbon/Varnish, and Average Sludge. The reference oils required for test stand and test laboratory calibration are reference oils accepted by the ASTM L-60-1 Surveillance Panel. The means and standard deviations for the current reference oils for each critical and noncritical parameter are presented below.

VISCOSITY INCREASE
Unit of Measure: VISI
CRITICAL PARAMETER

Reference Oil	Mean	Standard Deviation
131-3	81.451	7.659
131-4	75.944	7.659
145	70.225	5.099
148-1	36.966	7.659
151-2	37.070	2.717
155-2	23.000	2.832

PENTANE INSOLUBLES
Unit of Measure: PEN
CRITICAL PARAMETER

Reference Oil	Mean	Standard Deviation
131-3	2.293	0.413
131-4	2.560	0.413
145	1.198	0.249
148-1	0.387	0.413
151-2	2.064	0.380
155-2	1.509	0.434

AVERAGE CARBON/VARNISH
Unit of Measure: ACV
CRITICAL PARAMETER

Reference Oil	Mean	Standard Deviation
131-3	1.111	0.511
131-4	1.053	0.511
145	6.329	0.747
148-1	8.306	0.511
151-2	8.801	0.517
155-2	8.760	0.708

AVERAGE SLUDGE
Unit of Measure: ASL
CRITICAL PARAMETER

Reference Oil	Mean	Standard Deviation
131-3	9.411	0.106
131-4	9.483	0.106
145	8.575	0.648
148-1	9.532	0.106
151-2	9.382	0.106
155-2	9.426	0.101

TOLUENE INSOLUBLES
Unit of Measure: TOL
NONCRITICAL PARAMETER

Reference Oil	Mean	Standard Deviation
131-3	0.554	0.249
131-4	0.923	0.249
145	1.217	0.409
148-1	0.257	0.249
151-2	1.329	0.394
155-2	1.109	0.530

B. Acceptance Criteria

1. New Test Stand

- A minimum of two (2) operationally valid calibration tests, with no stand Shewhart severity alarms (all parameters) and no stand Shewhart precision alarms (critical parameters only), must be conducted on any approved reference oils assigned by the TMC.

- All operationally valid calibration test results 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.

2. Existing Test Stand

- The test stand must have been an ASTM TMC calibrated test stand prior to LTMS introduction or have previously been accepted into the system by meeting LTMS calibration requirements.

- All operationally valid calibration test results 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.

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 following reference oil mix:

- 100% of scheduled calibration tests should be conducted on reference oils 145 and 155-1, or subsequent approved reblends, on a 50/50 basis.

4. Control Charts

In Section 1 of the LTMS, the construction of the control charts that constitute the Lubricant Test Monitoring System is outlined. The constants used for the construction of the control charts for the L-60-1, and the response necessary in the case of control chart limit alarms, are depicted below.

LUBRICANT TEST MONITORING SYSTEM CONSTANTS

		EWMA Chart				Shewhart Chart	
		LAMBDA		K		K	
Chart Level	Limit Type	Precision	Severity	Precision	Severity	Precision	Severity
Stand	Warning	0.2	--	2.235	--	--	--
	Action	0.2	0.2	2.81	1.96	2.10	1.80
Lab	Action	0.2	0.2	2.81	3.03	--	1.80
Industry	Warning	0.15	0.15	2.235	2.49	--	--
	Action	0.15	0.15	2.81	3.03	--	--

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.

- Exceed EWMA test stand chart action limit for precision (critical parameters only)
  - Remove test stand from the system. Notify the TMC. Correct test stand precision problem. Follow requirements for entry of a new test stand into the system.
- Exceed EWMA test stand chart warning limit for precision (critical parameters only)
  - Immediately begin two calibration tests on the test stand.

ISB Reference Oil Targets							
Oil	n	Effective Dates		Average Camshaft Wear		Average Tappet Weight Loss	
		From	To[1]	$\overline{X}$	s	$\overline{X}$	s
821 (PC10E)	6	6-4-05	12-31-05	34.6	4.6	56.2	9.6
830-2	6	6-4-05	12-31-05	39.8	9.0	85.9	16.0
831 (PC10B)	6	6-4-05	1-24-07	41.9	5.6	88.7	15.9
	10	1-25-07	8-6-07	42.8	5.4	94.9	15.3
	14	8-7-07	***	42.5	5.0	97.2	14.8
831-1[2]	--	8-7-07	10-18-17	42.5	5.0	97.2	14.8
831-1[2]	--	10-19-17	***	42.5	8.7	97.2	14.8
831-2[2]	--	8-6-13	10-18-17	42.5	5.0	97.2	14.8
831-2[2]	--	10-19-17	***	42.5	8.7	97.2	14.8
831-3[2]	--	8-11-15	10-18-17	42.5	5.0	97.2	14.8
831-3[2]	--	10-19-17	9-03-20	42.5	8.7	97.2	14.8
831-3	--	9-4-20	6-30-24	52.4	9.2	97.2	14.8
831-1[3]	--	7-1-24	***	3.7495	0.2302	9.8590	1.1755
831-4[2]	--	6-14-17	10-18-17	42.5	5.0	97.2	14.8
831-4[2]	--	10-19-17	9-03-20	42.5	8.7	97.2	14.8
831-4	--	9-4-20	6-30-24	52.4	9.2	97.2	14.8
831-4[3]	--	7-1-24	***	3.7495	0.2302	9.8590	1.1755
835[3]	8	7-1-24	***	3.9338	0.2302	9.7057	1.1755

1 *** = currently in effect
2 Targets based on oil 831
3 Transformed units LN(ACSW) and SQRT(ATWL)

L-37-1 Reference Oil Targets																		
Hardware	Pinion Batch	Oil	n	From[1]	To[2]	Ridging			Rippling			Spitting			Wear			
						$\overline{X}$	s	Bands	$\overline{X}$	s	Bands	$\overline{X}$	s	Bands	$\overline{X}$	s	Bands	
UNCOATED	Gleason 04-2014, 06-2018, 2019/20	134/134-1	24	20200521	***	4.1	0.9	-	7.4	1.4	-	7.9	2.0	-	5.3	0.9	-	
		152-2	28	20200521	***	9.0	0.8	-	8.3	1.2	-	9.9	0.1	-	7.6	0.7	-	
		155-1/155-2	21	20200521	***	9.5	0.5	-	8.6	1.1	-	9.9	0.0	-	7.5	0.7	-	
MNP-COATED	Gleason 04-2014	134/134-1	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	-	
		155-1/155-2	9	20191001	***	9.3	1.0	-	8.7	0.7	-	9.9	0.0	-	7.9	0.8	-	
	Gleason 04-2021	134/134-1	6	20230510	***	-	-	4 - 6	-	-	5 - 8	-	-	9.8-9.9	-	-	6 - 7	
		152-2	5	20230510	***	-	-	8 – 10	-	-	7 – 9	-	-	9.9-10.0	-	-	7 – 8	
		155-1/155-2	7	20230510	***	-	-	8 – 10	-	-	7 – 9	-	-	9.8-10.0	-	-	7 – 8	

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

L-60-1 Reference Oil Targets													
		Effective Dates		Viscosity Increase		Pentane Insolubles		Toluene Insolubles		Average Carbon/Varnish		Average Sludge	
Oil	n	From[1]	To[2]	$\overline{X}$	s^3	$\overline{X}$	s^3	$\overline{X}$	s^3	$\overline{X}$	s^3	$\overline{X}$	s^3
131-3	30	6-3-94	***	81.451	7.659	2.293	0.413	0.554	0.249	1.111	0.511	9.411	0.106
131-4	--	11-2-95	***	75.944	7.659	2.560	0.413	0.923	0.249	1.053	0.511	9.483	0.106
133	9	8-23-00	***	93.691	7.659	2.801	0.413	1.405	0.249	6.548	0.511	9.381	0.106
143	30	6-3-94	***	31.500	7.659	1.271	0.413	0.914	0.249	9.002	0.511	9.503	0.106
145	8	2-26-25	***	70.225	5.099	1.198	0.249	1.217	0.409	6.329	0.747	8.575	0.648
148	30	6-3-94	***	36.966	7.659	0.387	0.413	0.257	0.249	8.306	0.511	9.532	0.106
148-1	--	3-11-02	8-9-23	36.966	7.659	0.387	0.413	0.257	0.249	8.306	0.511	9.532	0.106
151-2	9	8-23-00	***	37.070	2.717	2.064	0.380	1.329	0.394	8.801	0.517	9.382	0.106
155-1	17	6-7-14	2-10-16	27.176	3.127	1.388	0.372	1.035	0.451	8.971	0.436	9.441	0.106
155-1	20	2-11-16	8-11-16	27.750	3.242	1.490	0.529	1.135	0.639	8.875	0.678	9.435	0.103
155-1	35	8-12-16	9-15-23	28.800	3.669	1.509	0.434	1.109	0.530	8.760	0.586	9.426	0.101
155-2	35	8-1-23	2-20-24	28.800	3.669	1.509	0.434	1.109	0.530	8.760	0.586	9.426	0.101
155-2	35	8-1-23	***	23.000	2.832	1.509	0.434	1.109	0.530	8.760	0.708	9.426	0.101

1 Effective for all tests completed on or after this date.
2 *** = currently in effect.
3 Standard deviations are pooled s values for all oils except 145, 151-2, 155-1, and 155-2.
4 155-2 Target Update on Feb 21, 2024 applied retroactively to all 155-2 runs since August 1, 2023.

History of Industry Correction Factors
Appendix B

Test Area	Effective		Condition	Description
	From	To		
1M-PC	None		All Tests	None
1K	None		All Tests	None
1N	May 1, 2004	September 27, 2005	All Tests	Add -1.135 to ln(TLHC+1)
	September 28, 2005	March 31,2015	All Tests	Add -0.451 to ln(TLHC+1)
	April 1,2015	***	All Tests on 1Y3998 Liners	Add 0.419954 to ln(TGF+1)
1P	None		All Tests	None
1R	None		All Tests	None
C13	None		All Tests	None
COAT	20190510	***	Batch A Oil Filters	Multiply AAVE4050 by 0.9606
	20221118	***	Batch B Oil Filters	Multiply AAVE4050 by 0.9310
ISB	April 21, 2011	October 18, 2017	All tests using batch B tappets with batch E, F, and G cams	Multiply ATWL by 0.637; Add -9.5 to ACSW
	December 11, 2011	November 12, 2012	All tests using batch C tappets with batch H cams	Multiply ATWL by 0.637; Add -9.5 to ACSW
	November 13, 2012	October 18, 2017	All tests using batch C tappets with batch H and J cams	Multiply ATWL by 0.711; Add -5.6 to ACSW
	None	October 18, 2017	All test using batch D tappets and batch K cams	Multiply ATWL by 1; Add -11.3 to ACSW
	October 19, 2017	September 3,2020	All tests using batch K cams with batch D tappets and batch E crossheads	Multiply ATWL by 0.7851; Add -18.5 to ACSW
	September 4, 2020	***	All tests using batch K cams with batch D tappets	Multiply ATWL by 0.7851; Multiply ACSW by 0.94
	September 4, 2020	***	All tests using batch L cams with batch E tappets	Multiply ATWL by 0.7851; Multiply ACSW by 0.77
	September 4, 2020	June 30, 2024	All tests using batch M cams with batch F tappets and batch F crossheads (and subsequent batches)	Multiply ATWL by 0.92; Multiply ACSW by 0.77
	July 1, 2025	***	All tests using batch F tappets (and subsequent batches)	Add -0.741 to SQRT(ATWL) Add -0.4552 to LN(ACSW)

Test Area	Effective		Condition	Description
	From	To		
T-12	***	***	All tests using UUXO Hardware	Multiply Average Top Ring Weight Loss by 0.849
				Multiply Average Cylinder Liner Wear by 0.566
				$\Delta Lead_{Final} = \exp[(\ln(\Delta Lead) \times 0.797)]$
				$\Delta Lead\ (250\text{-}300)_{Final} = \exp[(\ln(\Delta Lead\ 250\text{-}300) \times 0.700)]$
				$OC = \exp[(\ln(OC_{100\text{-}300}) \times 0.916)]$
	***	***	All tests using VXYPD Hardware	Multiply Average Top Ring Weight Loss by 0.846
				$ALW_{Final} = \exp[(\ln(ALW) \times 0.743)]$
				If $OC_{100\text{-}300} > 65.0$ $\Delta Lead_{Final} = \exp[(\ln(\Delta Lead) + (65.0 - OC_{100\text{-}300}) \times 0.03234]$ If $OC_{100\text{-}300} \leq 65.0$ $\Delta Lead_{Final} = \Delta Lead$
				If $OC_{100\text{-}300} > 65.0$ $\Delta Lead(250\text{-}300)_{Final} = \exp[\ln(\Delta Lead(250\text{-}300) + (65.0 - OC_{100\text{-}300}) \times 0.04089]$ If $OC_{100\text{-}300} \leq 65.0$ $\Delta Lead(250\text{-}300)_{Final} = \Delta Lead(250\text{-}300)$
				$OC = \exp[(\ln(OC_{100\text{-}300}) \times 0.926)]$
	***	***	All tests using WYZQ Hardware and Delo Coolant	Multiply Average Top Ring Weight Loss by 0.846
				$ALW_{Final} = \exp[(\ln(ALW) \times 0.743)]$
				If $OC_{100\text{-}300} > 65.0$ $\Delta Lead_{Final} = \exp[(\ln(\Delta Lead) + 0.4696 + (65.0 - OC_{100\text{-}300}) \times 0.03234]$ If $OC_{100\text{-}300} \leq 65.0$ $\Delta Lead_{Final} = \Delta Lead$
				If $OC_{100\text{-}300} > 65.0$ $\Delta Lead(250\text{-}300)_{Final} = \exp[\ln(\Delta Lead(250\text{-}300) + 0.6079 + (65.0 - OC_{100\text{-}300}) \times 0.04089]$ If $OC_{100\text{-}300} \leq 65.0$ $\Delta Lead(250\text{-}300)_{Final} = \Delta Lead(250\text{-}300)$
				$OC = \exp[(\ln(OC_{100\text{-}300}) \times 0.926)]$

Test Area	Effective		Condition	Description
	From	To		
T-13	***	***	All Tests on Batch B Cylinder and subsequent liners	Transformed Result + 0.857
RFWT	None		All Tests	None
EOAT	None		All Tests	None
T-12A	None		All Tests	None
DD13	None		All Tests	None

Test Area	Effective From	Effective To	Condition			Description
L-33-1	20200102	***	AAM K2XX & T1XX			Add +1 to rated areas 2 and 3. Do not exceed 10.
L37	20010612	***	V1L686/P4L626A Non-reference	MNP-Coated Ring	Canadian	Ridging add 0.9922
	20040825	***	V1L686/P4L626A Non-reference	MNP-Coated Pinion & Ring	Canadian	Ridging add 0.6065
	***	***	L247/T758A Non-reference	MNP-Coated Pinion	Canadian	Ridging add 0.5878, Pitting/Spalling add 0.7340
	***	20130514	V1L528/P4T883A Non-reference	Uncoated Pinion	Standard	Ridging add 0.3365, Rippling add 0.3365
					Canadian	Rippling add 0.7885
				MNP-Coated Pinion	Standard	Ridging add 0.3365
					Canadian	Ridging add 0.5878, Rippling add 0.5878
				MNP-Coated Ring	Canadian	Ridging add 0.3365
	20130515	***	V1L528/P4T883A Non-reference	Uncoated Pinion	Standard	Ridging add 0.3365, Rippling add 0.3365
					Canadian	Rippling add 0.7566
				MNP-Coated Pinion	Standard	Ridging add 0.3365
					Canadian	Ridging add 0.5878, Rippling add 0.5878
				MNP-Coated Ring	Canadian	Ridging add 0.3365
L-37-1	None	***	All Tests			None
L-42	20140529	***	All reference oil tests using oil 117			Add 6% to pinion scoring result and add 4% to ring scoring result
L-60-1	20151001	***	All tests			Add 0.6 merits to ACV
HTCT			None			None
OSCT			None			None

Test Area	Effective From	Effective To	Condition	Description
D874	None		All Tests	None
D5800	None		All Tests	None

History of Industry Correction Factors
Appendix B

Test Area	Effective		Condition	Description
	From	To		
D5133 (GI)	None		All Tests	None
D6082	None		All Tests	None
D6417	None		All Tests	None
D6335 (TEOST)	None		All Tests	None
D7097 (MTEOS)	None		All Tests	None
D7528 (ROBO)	None		All Tests	None