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30. L-33-1 LTMS Requirements

The following are the specific L-33-1 calibration test requirements.

A. Reference Oils and Critical Parameter

The critical parameter is Final Rust. The reference oils required for test stand and test laboratory calibration are reference oils accepted by the ASTM L-33-1 Surveillance Panel. The mean and standard deviations for the current reference oils for the critical parameter are presented below.

FINAL RUST
Unit of Measure: Merits
Gear Versions V99.1 & V01.1

| Reference Oil | Mean | Standard Deviation |
|---------------|-------|--------------------|
| 123 | 8.560 | 0.230 |
| 123-2 | 8.740 | 0.260 |
| 151-3 | 9.640 | 0.250 |
| 155 | 9.580 | 0.250 |
| 155-1 | 9.580 | 0.250 |

FINAL RUST
Unit of Measure: Merits
Gear Version AAM K2XX & T1XX

| Reference Oil | Mean | Standard Deviation |
|---------------|------|--------------------|
| 123-2 | 8.51 | 0.35 |
| 155-1 | 9.47 | 0.16 |

B. Acceptance Criteria

1. New Test Stand

- A minimum of two (2) operationally valid calibration tests, with no stand Shewhart severity alarms, 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

| L-33-1 Reference Oil Targets | | | | | | |
|------------------------------|---------------|-----------------|-------------------|----------|---------------------|---------------------|
| Oil | Gear Version | n | Effective Dates | | Rust | |
| | | | From ¹ | To | \bar{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 | 0-01-20 | 8.12 | 0.38 |
| | AAM K2XX | 19 | 01-02-20 | 08-31-20 | 8.37 | 0.39 |
| | K2XX & T1XX | 37 | 09-01-20 | *** | 8.51 | 0.35 |
| 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 | 01-01-20 | 9.25 | 0.22 |
| | AAM K2XX | 20 | 01-02-20 | 08-31-20 | 9.47 | 0.13 |
| | K2XX & T1XX | 42 | 09-01-20 | *** | 9.47 | 0.16 |

- 1 Effective for all tests completed on or after this date. 7 Based on V99.1 and V95.1 data.
2 Based on V94.1 & V95.1 data. 8 Based on lab pooled s of V94.1 & V95.1 data (all blends of oil 123).
3 Based on oil 121 data. 9 Based on oil 123 data.
4 Based on lab pooled s of V94.1 & V95.1 data (all blends of oil 121). 10 Based on V99.1 data on oil 123.
5 Based on oil 121-1 data. 11 Based on V99.1 data on oil 151-3.
6 Based on V99.1 data on oil 121-1. 12 Based on V99.1 & V01.1 data on oil 151-3.

History of Industry Correction Factors
Appendix B

| Test Area | Effective | | Condition | | | Description | |
|--------------------|-----------|---|---------------------------------------|---------------------------------|-----------------------|---|---|
| | From | To | | | | | |
| 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 | Lubrited Ring | Canadian | Ridging add 0.9922 | |
| | 20040825 | *** | V1L686/P4L626A Non-reference | Lubrited Pinion & Ring | Canadian | Ridging add 0.6065 | |
| | *** | *** | L247/T758A Non-reference | Lubrited Pinion | Canadian | Ridging add 0.5878, Pitting/Spalling add 0.7340 | |
| | *** | 20130514 | V1L528/P4T883A Non-reference | Nonlubrited Pinion | Standard | Ridging add 0.3365, Rippling add 0.3365 | |
| | | | | | Canadian | Rippling add 0.7885 | |
| | | | | | Lubrited Pinion | Standard | Ridging add 0.3365 |
| | 20130515 | *** | V1L528/P4T883A Non-reference | Lubrited Pinion | Canadian | Ridging add 0.5878, Rippling add 0.5878 | |
| | | | | | Lubrited Ring | Canadian | Ridging add 0.3365 |
| | | | | | Nonlubrited Pinion | Standard | Ridging add 0.3365, Rippling add 0.3365 |
| | | | | | | Canadian | Rippling add 0.7566 |
| Lubrited Pinion | Standard | Ridging add 0.3365 | | | | | |
| | Canadian | Ridging add 0.5878, Rippling add 0.5878 | | | | | |
| 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 | | Condition | Description |
|-----------|-----------|----|-----------|-------------|
| | From | To | | |
| D874 | None | | All Tests | None |
| D5800 | None | | All Tests | None |

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

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

² 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.

³ 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.

⁴The 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 Laboratory/New Test Stand(s)

- a. The TMC calibration auditing system calibrates individual test stands at individual laboratories. There are no requirements to bring a lab into TMC calibrated status, there are only requirements to bring individual test stands into TMC calibrated status, as follows:
- b. Prior to obtaining calibration test oils from the TMC, new laboratories introducing a test stand must demonstrate their stand can successfully run all three (3) current TMC calibration oils within the TMC acceptance bands. Upon acceptance of these results by the TMC, the lab may request the two test calibration.
- c. A minimum of two (2) operationally valid calibration tests which fall within the acceptance bands for the oils assigned are required to calibrate a stand for the first time. These must be back-to-back consecutive runs on the same test stand, though exceptions can be made at the sole discretion of the TMC for operational fails for reasons that would be considered to have had no bearing on the operational performance of the test stand for subsequent tests (for example, a power failure).
- d. Passing two back-to-back consecutive TMC calibrations places the new test stand in TMC calibrated status. Both tests must pass on operational and statistical criteria.
- e. TMC calibrated status of a test stand is valid for no more than 50 days from date completed of a valid TMC calibration (that is, the end of the test's 40-hour oil oxidation heating cycle), or no more than 15 subsequent test starts on the stand (as counted sequentially by run number; see Item 3), whichever comes first. To renew the calibration at the end of the calibration period, see Item 2 for Existing Laboratory/Test Stand(s).

2. Existing Laboratory/New Test Stand(s)

- a. The TMC calibration auditing system calibrates individual test stands at individual laboratories. There are no requirements to bring a lab into TMC calibrated status, there are only requirements to bring individual test stands into TMC calibrated status, as follows:
- b. A minimum of two (2) operationally valid calibration tests which fall within the acceptance bands for the oils assigned are required to calibrate a stand for the first time. These must be back-to-back consecutive runs on the same test stand, though exceptions can be made at the sole discretion of the TMC for operational fails for reasons that would be considered to have had no bearing on the operational performance of the test stand for subsequent tests (for example, a power failure).

- c. Passing two back-to-back consecutive TMC calibrations places the new test stand in TMC calibrated status. Both tests must pass on operational and statistical criteria.
- d. TMC calibrated status of a test stand is valid for no more than 50 days from date completed of a valid TMC calibration (that is, the end of the test's 40-hour oil oxidation heating cycle), or no more than 15 subsequent test starts on the stand (as counted sequentially by run number; see Item 3), whichever comes first. To renew the calibration at the end of the calibration period, see Item 2 for Existing Laboratory/Test Stand(s).

3. Existing Laboratory/Existing Test Stand(s)

- a. An existing TMC calibrated test stand, or one where the TMC calibrated status had expired within the past 150 days, can renew its TMC calibrated status by demonstrating a successful calibration on another single TMC blind calibration audit. The test must pass on both operational and statistical criteria.
- b. TMC calibrated status of an existing test stand is valid for no more than 50 days from date completed of a valid TMC calibration (that is, the end of the test's 40-hour oil oxidation heating cycle), or no more than 15 subsequent test starts (as counted sequentially by run number) on the stand, whichever comes first. Test stands that exceed these time/run specifications are considered to be out of calibration for TMC monitoring purposes.
- c. A stand that has been out of TMC calibration for more than 150 days from the prior TMC calibration expiration date will require New Test Stand calibration as listed in B.2.b through B.2.d. of this document.
- d. A stand must pass the TMC calibration within two operationally valid test runs. If a stand cannot produce a calibration test that falls into the acceptance bands for the assigned oil within two operationally valid runs. Renewing calibration on that stand will require the two test calibration as listed in B.2.b through B.2.d.
- e. Changing the vacuum control valve set point, exchanging the reactor vessel or the vacuum pump, or changing the heating voltage setting by more than ± 1 volt on a stand for any reason voids any current TMC calibrated status. Renewing calibration on that stand will require the two test calibration as listed in B.2.b through B.2.d.

4. Tracking and Reporting Stand Runs

- a. Tracking a stands calibration status by run number will be effected by tracking and reporting Instrument ID and Run Number to the TMC. Run Number shall 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.

5. 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% |

6. 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.

7. 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.

20. 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: Micrometers

| Reference Oil | Mean | Standard Deviation |
|---------------|------|--------------------|
| 831-3 | 52.4 | 9.2 |
| 831-4 | 52.4 | 9.2 |

AVERAGE TAPPET WEIGHT LOSS Unit of Measure: Milligrams

| Reference Oil | Mean | Standard Deviation |
|---------------|------|--------------------|
| 831-3 | 97.2 | 14.8 |
| 831-4 | 97.2 | 14.8 |

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.

3. Reference Oil Assignment

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: | $SA = (-Z_i) \times (8.5)$ |
| Average Tappet Weight Loss: | $SA = (-Z_i) \times (14.8)$ |

- 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.

| ISB Reference Oil Targets | | | | | | | |
|---------------------------|----|-----------------|-----------------|-----------------------|-----|----------------------------|------|
| Oil | n | Effective Dates | | Average Camshaft Wear | | Average Tappet Weight Loss | |
| | | From | To ¹ | \bar{X} | s | \bar{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 | *** | 52.4 | 9.2 | 97.2 | 14.8 |
| 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 | *** | 52.4 | 9.2 | 97.2 | 14.8 |

1 *** = currently in effect

2 Targets based on oil 831

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 | None | | All Tests | None |
| 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 |

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

| Test | Parameter | s | Effective Dates | |
|------|------------------------------------|------|-----------------|----------|
| | | | From | To |
| ISB | Camshaft Wear | 8.7 | 20171129 | 20200903 |
| | | 8.5 | 20200904 | *** |
| | Tappet Wt. Loss | 14.8 | 20171129 | *** |
| ISM | X-Head Wear | None | -- | -- |
| | OFDP | None | -- | -- |
| | Average Sludge | None | -- | -- |
| | Adj. Screw Wear | None | -- | -- |
| T-8 | Vis. Inc. @ 3.8% | 1.19 | 19940401 | 19960930 |
| | | 0.93 | 19961001 | 19990131 |
| | | 0.90 | 19990201 | 20070524 |
| | | 0.00 | 20070525 | 20110916 |
| | | 0.56 | 20110917 | *** |
| T-8E | Rel. Vis. @ 4.8% 50% DIN Shear | 0.26 | 19970127 | 20070524 |
| | | 0.00 | 20070525 | 20110916 |
| | | 0.08 | 20110917 | *** |
| | Rel. Vis. @ 4.8% 100% DIN Shear | 0.27 | 20020306 | 20070524 |
| | | 0.00 | 20070525 | 20110916 |
| | | 0.09 | 20110917 | *** |
| 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 | 20200729 |
| | MRV Viscosity | 1117 | 20200730 | *** |

37. D5133 (GI) TMC Calibration Requirements

The following are the specific D5133 (GI) TMC calibration test requirements.

Objective of TMC monitoring of D5133 (GI) test stands: The surveillance panel's intent is that each participating GI instrument head (viscometer drive module) and test cell (rotor and stator) combination must demonstrate accurate D5133 test performance on blind reference oils of known and varied GI severity performances at least once every 180 days, and demonstrate a passing result on a low-gelling (discrimination) reference oil every other calibration run (or, at least once every 360 days). The following requirements are intended to meet these objectives.

A. Reference Oils and Critical Parameters

1. The critical pass/fail parameter is Gelation Index (a unitless, derived value that measures the gelling tendency characteristics of a tested fluid). The reference oil performance targets and acceptance criteria required for calibration with the TMC are listed in Table 1 and have been approved by the ASTM D02.B0.07 Gelation Index Surveillance Panel.
2. Per the D5133 test method, a GI result less than 6.0 shall be reported as '<6.0', and GI result of 6.0 or greater shall be reported as a numeric value to one decimal.

Table 1
D5133 Reference Oil Targets and Acceptance Bands

| Test | Oil Code | Parameter | n | Mean | sR | Acceptance Bands* | |
|----------------|----------|--|----|------|------|-------------------|-------|
| | | | | | | Lower | Upper |
| GI by D5133 | 1009 | Gelation Index | 16 | 7.3 | 0.68 | 6.0 | 8.6 |
| | 62 | Gelation Index | 35 | 17.0 | 3.90 | 9.4 | 24.6 |
| | GIA17 | Gelation Index | 18 | 19.0 | 1.87 | 15.4 | 22.7 |
| | 58 | Gelation Index (Discrimination Oil) | 17 | <6.0 | N/A | <6.0 | 7.2 |

*95% Acceptance Bands = Mean +/- (1.960 x sR)

B. Test Stand Defined

1. A GI test stand is defined as a single Scanning Brookfield head (also referred to in the test method as a 'Viscometer Drive Module'), and a single rotor and stator (test cell) combination and in conformance with ASTM Test Method D5133. The test sample and test cell may be cooled by liquid bath, air or thermoelectrically. The test cell may be cooled in a common cooling bath with other test cells, or by temperature controlled blocks with one or more test cells. Each stand (head and test cell combination) is to be identified by a unique manufacturers head serial number.
2. Testing labs are permitted to limit participation to any number of test stands on a multi-head instrument (or controller) with this notification that any test stands that are not

specifically TMC calibrated under the specifications in this document cannot be used as, or implied to be, TMC calibrated test stands, heads or test cells.

C. Acceptance Criteria

1. New Laboratory/Test Stand(s)

- a. All new test stands must first demonstrate acceptable discrimination performance by meeting the acceptance criteria on three *consecutive* blind test stand calibration runs using a TMC severe (high GI) performing GI reference oil, a TMC borderline-low GI performing reference oil, and a discrimination (low to non-gelling) GI reference oil with no significant instrument settings or changes between the runs. See Section C.2.h for a list of test stand changes considered to be operationally significant.
 1. Operational conformance as well as statistical evaluation of the reported test results will be reviewed to make validity determinations. Test stands that successfully pass the initial three-test calibration/discrimination requirement are considered to be TMC calibrated until the test stand calibration expires.
 2. A test stand that fails on either operational conformance or the statistical acceptance criteria will need to have the three-test runs repeated until a passing blind three-test sequence is achieved on the individual test stand.
 3. The passing consecutive three-test calibration/discrimination runs on a stand must occur within a period of 21 calendar days, as determined by date completed. Intervals of more than 21 days between three required consecutive stand calibration/discrimination runs, as determined by date completed, will operationally disqualify the test stand calibration attempt.
 4. The run order of the three initial required tests can be in any order, but must be consecutive, back-to-back runs.
 5. All three tests of a new test stand calibration sequence must be reported before any of the test results will be evaluated for validity by the TMC.
- b. TMC calibrated status of a test stand is valid for not more than 180 days from date completed of most recent of the two valid *calibration* runs (that is, the end of the test's cooling cycle needed to generate the second GI calibration test value). The date completed of the discrimination run will not be used in calculating calibration periods.
- c. To renew the calibration at the end of the calibration period, see Section C.2 for Existing Laboratory/Test Stand(s).

2. Existing Laboratory Test Stand(s)

- a. To maintain calibrated status, all participating test stands must demonstrate a single passing blind calibration performance at least once every 180 days. An

existing TMC calibrated test stand, or one where the TMC calibrated status has expired for not more than 90 days, can renew its TMC calibrated status by demonstrating a successful blind calibration on at least one TMC blind calibration run on a current or recently calibrated test stand. This test must pass on both operational and statistical criteria.

- b. For single-test blind calibrations, blind calibration samples will be assigned in approximate equal frequency from among the current surveillance panel approved reference oils.
- c. To maintain calibrated status of the test stand, a successful passing discrimination run must also be run and reported at least every 360 days, and coincident with a blind calibration run, per Section C.5.
- d. TMC calibrated status of an existing test stand is valid for no more than 180 days from date completed of a valid TMC calibration (that is, the end of the test's cooling cycle needed to generate the GI calibration test value).
- e. Test stands that exceed the time periods specified in either Sections C.2.a or C.2.c for calibration or discrimination runs are considered to be out of calibration for TMC monitoring purposes.
- f. A test stand that has been out of TMC calibration for more than 90 days past the prior TMC test stand calibration expiration date will require a New Test Stand calibration as specified in Section C.1.
- g. A single-test stand calibration must pass the TMC calibration within two operationally valid calibration attempts, and within 14 days of each other. If a stand cannot produce a calibration test that falls into the acceptance bands for the assigned oil within two operationally valid runs, and within 14 days from the first failing attempt, renewing calibration on that stand will require a New Test Stand calibration as specified in Sections C.1.
- h. Any of the following significant changes voids any current TMC calibrated status and will require a New Test Stand calibration as specified in Sections C.1. The lab will add test comment to report reason for calibration.
 - Replacement or exchange of a head, rotor or stator in a test stand.
 - Replacement of a test cell previously matched and calibrated with a head.
 - Repair of a head or test cell.
- i. The following changes would void the current TMC calibration status of a test stand and require a new single calibration as required in section C.2. The lab will add test comment to report reason for calibration.
 - Moving a test stand (previously matched and calibrated head and test cell) to a new bath, cooling block or controller.
- j. The following changes would require a calibration run of one test stand on the controller system. The lab will add test comment to report reason for calibration.

- Repair of a central controller
- Replacement of a cooling bath thermocouple

In the event of a failing calibration run, the lab shall verify the change was not the reason for the failure by running a calibration run on another test stand on the same controller system. The failing test stand will follow the calibration requirement listed in section C.2.

3. Tracking and Reporting Test Stand Runs

- a. Tracking a stands calibration status by run number will be effected by tracking and reporting Instrument ID and Head Run Number to the TMC. Instrument ID and Run Number are separate fields on the approved data dictionary. An example is:

| | |
|------------------|--------------|
| Instrument ID: | C123456(C20) |
| Head Run Number: | 123456 (C10) |

- b. Instrument ID shall be the serial number of the head that produced the test result being reported, and represents the monitored test stand. Repaired or overhauled heads will be reset in the test monitoring system per Section C.6.b.
- c. Head Run Number shall be a consecutive integer count of test starts on a head. Head Run Number is increased incrementally by one (1) for each new test start on a head, regardless of whether or not the test runs to completion, or whether or not the run is a TMC calibration attempt. Head Run Number will be reset to 1 for new or newly repaired heads.

4. Blind Calibration Test Evaluation:

- a. The calibration status of a test stand will be based on a review of reported operational parameters for compliance with the test method, followed by a statistical evaluation of the critical parameter test result against the acceptance ranges in Section A (commonly referred to as a Shewhart severity evaluation). Unless otherwise noted, the acceptance bands in Table 1 are based on a 95% confidence treatment of round robin test results with data exclusions as approved by the surveillance panel.
- b. Unless otherwise addressed by the panel, any operationally valid GI test result reported as '<6.0' for any non-discrimination reference oil cannot be statistically interpreted. Such reported test results will be given a validity that indicates the result is operationally valid but not statistically interpretable, and therefore not chartable. (Validity OC, Chart N)

5. Discrimination Oil Test Criteria:

- a. In order to demonstrate that the test stand can discriminate a borderline non-gelling oil from the reference oils that have measurable gelling characteristics, a low-to-non-gelling discrimination oil (TMC oil 58 or an approved replacement) shall be requested and assigned on every calibrated test stand

initially (per C.1.a) and at least once every 360 days, and run consecutively with a blind calibration run,. Operational conformance will be evaluated, as will the GI test result per Table 1. However, the discrimination test results will not be otherwise statistically evaluated (non-chartable). A GI result less than 6.0 shall be reported as '<6.0', and GI result of 6.0 or greater shall be reported as a numeric value to one decimal. TMC pass/fail evaluation of the discrimination run will be based on the approved upper acceptance limit for the discrimination oil (see Table 1). A special discrimination run validity and comment will be applied, but the discrimination test result will not be otherwise statistically interpreted.

- b. A test stand must pass the acceptance criteria in Table 1 for the discrimination oil within two attempts. Failure of the first attempt on a discrimination run, while passing on the concurrent calibration run on the same test stand, will place the calibration status of the affected test stand as pending while a discrimination oil rerun is conducted. The discrimination test rerun must be completed within 14 days from the prior failing run. Passing a second consecutive discrimination run (following a failed discrimination attempt) will reinstate the calibrated status of the test stand until the test stand calibration expiration date (specified on the calibration test confirmation report). Two consecutive runs that fail to meet the acceptance criteria for the discrimination oil will void the current calibrated status of the test stand and require a full new stand calibration sequence as defined in section C.1. Shakedown runs will be permitted to troubleshoot stand performance before proceeding with the three-test calibration sequence.
- c. Failure of a lab to perform and report a discrimination run to the TMC in the time period referenced in section C.2.a and C.2.c voids the current calibrated status of the test stands and require a new stand calibration sequence as specified under section C.1.
- d. It is the referencing lab's responsibility to track when discrimination runs are due, the TMC will not send reminders on this.

6. Replacement or Repair of Heads:

- a. Repaired or refurbished heads, and/or repaired or replaced rotors or stators will be considered as new test stands and must be (re)introduced with a successful new test stand calibration sequence, as specified in section C.1.
- b. Repaired or refurbished heads, or replaced test cells, will add a suffix to the Head ID starting with '-R1' and increasing numerically ('-R2', '-R3'...) following each successive repair. Head Run Number will be reset to 1 for new or newly repaired heads or replaced test cells, reflecting a new test stand and run count series for each new or newly repaired Head ID.

7. Removal of Test Stands from the System

- a. 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 as a new test stand per section C.1.

8. Introduction of New or Re-Blended Reference Oils
 - a. 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 D5133 (GI) test. The number of tests requested will be sufficient to rigorously evaluate the oil's performance (typically a minimum of 15 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 by the panel as the TMC collects additional calibration data.

9. Internal Calibration of Test Stand
 - a. In addition to the TMC blind calibrations, Test Method D5133 specifies a separate calibration check for each test cell. To differentiate this requirement from the TMC calibrations, this is to be referred to in the data dictionary as an 'internal calibration'. The internal calibration is to be successfully performed as specified in the test method. The date of the last internal calibration is to be reported to the TMC with the TMC calibration run results for the test stand being reported. As part of the operational review, the TMC will confirm that the date completed of the most recent internal calibration (DTINTCAL) is prior to, and within the time specified in the test method, from date completed of the TMC calibration (DTCOMP) for each test stand. Test stands found to have delinquent test cell internal calibrations from the test method specification will be evaluated as operationally invalid.

10. Transitioning current registered instruments from an instrument based calibration monitoring system to a head-test cell based monitoring system:
 - a. From the first day of implementing the head-test cell based test stand system, ALL current head calibrations will expire within 180 days of implementation. Labs with existing calibrated *baths* will have up to 180 days to newly recalibrate all *heads* with current calibrations as newly defined *test stands* by completing a single-test calibration followed consecutively by a discrimination oil run on each head/test cell (test stand), under the specifications in this document.
 - b. Any heads with current calibrations expiring prior to 180 days from the implementation of this document will need to be recalibrated as test stands by the head calibration expiration date shown on the most recent TMC Test Confirmation Report (TCR) for each currently calibrated head. This will require completing a single-test calibration followed consecutively by a discrimination oil run on each head/test cell (test stand), under the specifications in this document. Head calibrations will not be extended beyond current expiration dates as a result of this transition.
 - c. . Statistics will be reset for monitoring test stands by newly registered head serial numbers as the Instrument ID.

| D5133 (GI) Test Reference Oil Targets | | | | | |
|---------------------------------------|----|-------------------|-----------------|----------------------|-------|
| Oil | n | Effective Dates | | Sulfated Ash, mass % | |
| | | From ¹ | To ² | \bar{X} | s |
| 1009 | 16 | 20030715 | *** | 7.3 | 0.68 |
| 51 | 10 | 19960401 | 19961231 | 65.4 | 12.6 |
| 51 | 35 | 19970101 | 20010702 | 63.3 | 12.01 |
| 52 | 11 | 19960401 | 19961231 | 4.4 | 0.20 |
| 52 | 35 | 19970101 | 20030714 | 4.5 | 0.24 |
| 53 | 11 | 19960401 | 19961231 | 45.3 | 3.70 |
| 53 | 37 | 19970101 | 20030714 | 44.7 | 4.64 |
| 55 | 10 | 19960401 | 19961231 | 22.6 | 5.10 |
| 55 | 36 | 19970101 | 20010702 | 22.3 | 4.84 |
| 58 | 17 | 20011024 | 20200930 | 5.8 | 0.69 |
| 58 ³ | 17 | 20201001 | *** | <6.0 | N/A |
| 62 | 10 | 19960401 | 19961231 | 15.7 | 4.70 |
| 62 | 35 | 19970101 | *** | 17.0 | 3.90 |
| GIA17 | 18 | 20190409 | *** | 19.0 | 1.87 |

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

45. D6794 Engine Oil Water Tolerance Test (EOWT) LTMS Requirements

The following are the specific Engine Oil Water Tolerance Test calibration test requirements.

A. Calibration Details

The Engine Oil Water Tolerance Test is calibrated at the laboratory level. No individual instruments are identified in the test method. The test can be run at one of four water treatment rates (0.6%, 1.0%, 2.0%, or 3.0%). Tests targets are maintained by water treatment rate, with each water treatment rate being evaluated separately.

B. Reference Oils and Critical Parameters

The critical parameter is the 20 – 25 mL Average Change in Flow Rate, reported in milliliters per second. The reference oils required for instrument calibration are the reference oils accepted by the ASTM EOWT Surveillance Panel. The mean, standard deviation, and acceptance band for the current reference oils for Average Change in Flow Rate are presented below.

20 – 25 mL AVERAGE CHANGE IN FLOW RATE (CFA)

Unit of Measure: mL/s

| 0.6% Water Treatment Rate | | | |
|---------------------------|--------|--------------------|------------------------------|
| Reference Oil | Mean | Standard Deviation | Acceptance Band ^A |
| 77-3 | -10.23 | 2.78 | -15.68 to -4.78 |
| 79 | 15.64 | 4.98 | 5.89 to 25.40 |

^ATest results are compared to the Acceptance Bands

| 1.0% Water Treatment Rate | | | |
|---------------------------|-------|--------------------|------------------------------|
| Reference Oil | Mean | Standard Deviation | Acceptance Band ^A |
| 77-3 | -7.82 | 2.34 | -12.41 to -3.23 |
| 79 | 13.74 | 4.84 | 4.25 to 23.24 |

^ATest results are compared to the Acceptance Bands

| 2.0% Water Treatment Rate | | | |
|---------------------------|-------|--------------------|------------------------------|
| Reference Oil | Mean | Standard Deviation | Acceptance Band ^A |
| 77-3 | -8.80 | 2.47 | -13.65 to -3.95 |
| 79 | 10.16 | 5.81 | -1.23 to 21.55 |

^ATest results are compared to the Acceptance Bands

| 3.0 % Water Treatment Rate | | | |
|----------------------------|--------|--------------------|------------------------------|
| Reference Oil | Mean | Standard Deviation | Acceptance Band ^A |
| 77-3 | -10.15 | 2.21 | -14.49 to -5.82 |
| 79 | 7.83 | 5.45 | -2.85 to 18.52 |

^ATest results are compared to the Acceptance Bands

C. Acceptance Criteria

1. New Laboratory

- Operationally valid calibration tests, with results within the Acceptance Bands, must be conducted on each of the reference oils 77-3 and 79, or subsequent approved reblends, at each water treatment rate tested. No candidate oils shall be tested along with these runs.

2. Existing Laboratory

- The laboratory must have been TMC calibrated prior to LTMS introduction or previously accepted into the system by meeting LTMS calibration requirements.
- An operationally valid calibration test, with a result within the Acceptance Band, must be conducted on reference oil 77-3 or 79, or subsequent approved reblends, with each group of candidate test runs, at each water treatment rate tested.

3. Reference Oil Assignment

Once a laboratory has been accepted into the system, the TMC will assign reference oils evenly distributed between 77-3 and 79, or subsequent approved reblends, for continuing calibration at each water treatment rate.

4. Control Charts

In Section 1, 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 Engine Oil Water Tolerance Test, and the response necessary in the case of control chart limit alarms, are depicted below. The Shewhart Chart is used to initially determine the Acceptance Band on a new reference oil, prior to rounding those results to establish the official Acceptance Band for that reference oil.

LUBRICANT TEST MONITORING SYSTEM CONSTANTS

| | | EWMA Chart | | | | Shewhart Chart | |
|-------------|------------|------------|----------|-----------|----------|----------------|----------|
| | | LAMBDA | | K | | K | |
| Chart Level | Limit Type | Precision | Severity | Precision | Severity | Precision | Severity |
| Stand | Action | -- | -- | -- | -- | -- | 1.96 |

The following are steps that must be taken in the case of a result outside the Acceptance Band.

- Result outside the Acceptance Band (all parameters)
 - Conduct an additional calibration test.

5. 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 D6794 EOWT test. The number of tests requested will be sufficient to rigorously evaluate the oil's performance (typically a minimum of 3 tests per lab per treat rate, 12 tests in total, for 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.

46. D6795 Engine Oil Filterability Test (EOFT) LTMS Requirements

The following are the specific Engine Oil Filterability Test calibration test requirements.

A. Calibration Details

The Engine Oil Filterability Test is calibrated at the laboratory level. No individual instruments are identified in the test method.

B. Reference Oils and Critical Parameters

The critical parameter is the 20 – 25 mL Average Change in Flow Rate, reported in milliliters per second. The reference oils required for instrument calibration are the reference oils accepted by the ASTM EOFT Surveillance Panel. The mean, standard deviation, and acceptance band for the current reference oil for Average Change In Flow Rate are presented below.

20 – 25 mL AVERAGE CHANGE IN FLOW RATE (CIFA)
Unit of Measure: mL/s

| Reference Oil | Mean | Standard Deviation | Acceptance Band ^A |
|---------------|-------|--------------------|------------------------------|
| 79 | 36.58 | 4.56 | 27.64 – 45.51 |

^ATest results are compared to the Acceptance Bands

C. Acceptance Criteria

1. New Laboratory

- Two operationally valid calibration tests, with results within the Acceptance Band, must be conducted on reference oil 79, or subsequent approved reblend. No candidate oils shall be tested along with these runs.

2. Existing Laboratory

- The laboratory must have been TMC calibrated prior to LTMS introduction or previously accepted into the system by meeting LTMS calibration requirements.
- An operationally valid calibration test, with a result within the Acceptance Band, must be conducted on reference oil 79, or subsequent approved reblend, with each group of candidate test runs.

3. Reference Oil Assignment

Once a laboratory has been accepted into the system, the TMC will assign reference oil 79, or subsequent approved reblend, for continuing calibration.

4. Control Charts

In Section 1, 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 Engine Oil Filterability Test, and the response necessary in the case of control chart

limit alarms, are depicted below. The Shewhart Chart is used to initially determine the Acceptance Band on a new reference oil, prior to rounding those results to establish the official Acceptance Band for that reference oil.

LUBRICANT TEST MONITORING SYSTEM CONSTANTS

| | | EWMA Chart | | | | Shewhart Chart | |
|-------------|------------|------------|----------|-----------|----------|----------------|----------|
| | | LAMBDA | | K | | K | |
| Chart Level | Limit Type | Precision | Severity | Precision | Severity | Precision | Severity |
| Stand | Action | -- | -- | -- | -- | -- | 1.96 |

The following are steps that must be taken in the case of a result outside the Acceptance Band.

- Result outside the Acceptance Band (all parameters)
 - Conduct an additional calibration test.

5. 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 D6795 EOFT. The number of tests requested will be sufficient to rigorously evaluate the oil's performance (typically a minimum of 3 tests per participating lab). 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.

47. D6557 Ball Rust Test (BRT) LTMS Requirements

The following are the specific Ball Rust Test calibration test requirements.

A. Calibration Details

The Ball Rust Test is calibrated at the individual instrument level, by the shaker table used in the test. Shaker tables are identified by ID number within a laboratory and calibrated individually. There is no laboratory level calibration in the Ball Rust Test.

B. Reference Oils and Critical Parameters

The critical parameter is Average Gray Value, reported in brightness units. The reference oils required for instrument calibration are the reference oils accepted by the ASTM Ball Rust Test Surveillance Panel. The mean, standard deviation, and acceptance band for the current reference oils for Average Gray Value are presented below.

AVERAGE GRAY VALUE (AGV)

Unit of Measure: brightness units

| Reference Oil | Mean | Standard Deviation | Acceptance Band ^A |
|---------------|-------|--------------------|------------------------------|
| 1006 | 128 | 7.21 | 114 – 142 |
| 82-1 | 49.2 | 16.40 | 17 – 82 |
| 86 | 119.6 | 10.30 | 99 – 140 |
| 87 | 121.8 | 8.50 | 105 – 139 |

^ATest results are compared to the Acceptance Bands

C. Acceptance Criteria

1. New Shaker Table

- An operationally valid calibration test, with results within the Acceptance Bands, must be conducted on all current reference oils, or subsequent approved reblends. These tests may be run simultaneously. No candidate oils shall be tested along with these runs.

2. Existing Shaker Table

- The instrument must have been TMC calibrated prior to LTMS introduction or previously accepted into the system by meeting LTMS calibration requirements.
- An operationally valid calibration test, with results within the Acceptance Bands, must be conducted on an approved reference oil, with every candidate test run on the shaker table.

3. Reference Oil Assignment

Once a shaker table has been accepted into the system, the TMC will assign an approved reference oil for continuing calibration according to the following proportions:

- 25% on reference oil 1006 (or subsequent approved reblends)
- 25% on reference oil 82-1 (or subsequent approved reblends)
- 25% on reference oil 86 (or subsequent approved reblends)

- 25% on reference oil 87 (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. The constants used for the construction of the control charts for the Ball Rust Test, and the response necessary in the case of control chart limit alarms, are depicted below. The Shewhart Chart is used to initially determine the Acceptance Band on a new reference oil, prior to rounding those results to establish the official Acceptance Band for that reference oil.

LUBRICANT TEST MONITORING SYSTEM CONSTANTS

| | | EWMA Chart | | | | Shewhart Chart | |
|-------------|------------|------------|----------|-----------|----------|----------------|----------|
| | | LAMBDA | | K | | K | |
| Chart Level | Limit Type | Precision | Severity | Precision | Severity | Precision | Severity |
| Stand | Action | -- | -- | -- | -- | -- | 1.96 |

The following are steps that must be taken in the case of a result outside the Acceptance Bands.

- Result outside the Acceptance Band (all parameters)
 - Conduct an additional calibration test.

5. 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 D6557 BRT. The number of tests requested will be sufficient to rigorously evaluate the oil's performance (typically a minimum of 3 tests per lab for 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.