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(APPENDIX F)

(TEMPLATES FOR VERSION 2 LABORATORY AND STAND BASED LTMS)

# Cummins ISB LTMS Requirements(A Laboratory Based Severity Adjustment System)

**TEST METHOD PORTION**

The following are the specific Cummins ISB calibration test requirements.

A. Reference Oils and Parameters

The prediction error monitoring severity adjustment 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 Surveillance Panel. The targets for the current reference oils for each parameter are presented below.

### Average Cam Shaft Wear

Unit of Measure: Micrometers

Prediction Error Monitoring and Severity Adjustment Parameter

|  |  |
| --- | --- |
| Reference Oil | Target |
| 831 | 42.5 |
| 831-1 | 42.5 |

### Average Tappet Weight Loss

Unit of Measure: Milligrams

Prediction Error Monitoring and Severity Adjustment Parameter

|  |  |
| --- | --- |
| Reference Oil | Target |
| 831 | 97.2 |
| 831-1 | 97.2 |

B. Acceptance Criteria

1. New test labs [It is preferred that the definition of a new laboratory appears in the test method. But if it doesn’t or requires clarification, it should be done here.]

a. A minimum of three (3) operationally valid reference and/or matrix tests with no level 3 ei alarms must be run on the first test stand in a new laboratory.

* Note that industry matrix runs may be included, as well as reference runs, at the discretion of the surveillance panel.

b. Following the necessary tests, check the status of the control charts and follow the prescribed actions.

c. If two full length reference oil tests are declared operationally invalid during the attempt to calibrate a stand, then an increase in the reference interval per section 5.d may not be granted.

2. Existing Test Lab

a. 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 Level 1 limit requirement is met. Otherwise a second test is required for calibration.

b. For an existing test stand in an existing lab run one test

c. Following an operationally valid reference oil calibration test, check the status of the control charts and follow the prescribed actions.

d. If two full length reference oil tests are declared operationally invalid during the attempt to calibrate a stand, then an increase in the reference interval per section 5.d may not be granted.

3. Reference Oil Assignment

Once a test stand has been accepted into the system, the TMC will assign reference oils for continuing calibration according to the following reference oil mix:

* 100% of the scheduled calibration tests should be conducted on reference oils 831 and 831-1 or subsequent approved reblends.

4. Chart Status

The following are the steps that must be taken in the case of exceeding 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.

a. Shewhart Chart of Prediction Error (ei) for **prediction error monitoring parameters only**

• Level 3

– Immediately conduct one additional reference test in the stand that triggered the alarm. Do not update the control charts for the lab until the follow up reference test is completed and the ExI analysis, per Section 5.c (below), has been performed.

• Level 2

– Reduce the number of tests allowed in the calibration period in the stand that triggered the alarm to [enter number of tests representing 80% of the standard calibration period].

• Level 1

* + The level 1 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 1 alarm is triggered, immediately conduct one additional reference test in the stand that triggered the alarm.
  + The level 1 limit also applies to a stand in an existing test lab that has not run an acceptable reference in the past two years. The stand can calibrate with one test if the level 1 limits are not exceeded. Otherwise, immediately conduct another reference test in the stand.

b. Reference entity EWMA of Standardized Test Result (Zi) for **all parameters**

• Level 2

* Immediately conduct one additional reference test either
  + in the stand that triggered the alarm, or
  + in the stand that is next due for calibration.
    - The stand that triggered the alarm is not calibrated for non-reference testing without further reference testing.

• 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 Zi to determine the laboratory severity adjustment (SA). Calculate the laboratory SA for each parameter as follows and confirm the calculation with the TMC:

SA = -Zi x sSA

where sSA =industry approved severity adjustment standard deviation

c. Excessive influence (ExI) Analysis for **prediction error monitoring parameters only**

* The ExI analysis is performed anytime that a lab ei level 3 alarm is triggered. As prescribed in Section 5.a, Level 3, a follow up reference test is run. The following comparisons then determine whether the value of Yi is modified to limit its influence on LTMS. Yi+1 is the next completed reference in the laboratory after the level 3 alarm

1. If |Yi – Yi+1| ≤ ei level 3 limit, then Yi is equal to the value originally determined.
2. If Yi > Zi-1 and Yi-Yi+1 > ei level 3 limit, then let

Yi = ei level 3 limit + Zi-1.

1. If Yi ≤ Zi-1 and Yi-Yi+1 < -ei level 3 limit, then let

Yi = -ei level 3 limit + Zi-1.

1. If none of i), ii), or iii) is true, then Yi is equal to the value originally determined.

Where: i = test that originally triggered level 3 alarm,

i-1 = test prior to alarm trigger, and

i+1 = test immediately following alarm trigger.

Once the proper Yi value has been determined, update the charts. Confirm calculations with the TMC. The laboratory and the TMC maintain a record of the modification.

d. Increase in the Number of Tests for the Stand Calibration Period

• The number of tests allowed in a stand calibration period, for existing stands only, may be increased if the previous test was an acceptable reference based upon the chart results for all prediction error monitoring parameters as follows:

* + If |ei| ≤ Ee, then the number of tests allowed for that calibration period may be increased by [insert number of tests representing 20% of the standard calibration period], [if surveillance panel opts to include “, and the time between references may be increased by” insert time extension required to extend number of tests or time period representing 20% of the standard period ], or
  + If |ei| ≤ Ee and |Zi|≤ EZ, then the number of tests allowed for that calibration period may be increased by [insert number of tests representing 40% of the standard calibration period] [if surveillance panel opts to include “,and the time between references may be increased by” insert time extension required to extend number of tests or time period representing 40% of the standard period “.

Confirm calculations with the TMC.

• If two full length reference oil tests are declared operationally invalid during the calibration sequence in the same stand, then the increase in calibration period will not be granted

e. Industry EWMA of Standardized Test Result (Zi) for **all parameters**

• 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.

**TMC COMPENDIUM PORTION**

The following are the specific Cummins ISB calibration test requirements.

A. Reference Oils and Parameters

The prediction error monitoring and severity adjustment parameters are Average Cam Shaft Wear (ACSW) and Average Tappet Weight Loss (ATWL). The reference oils required for test stand and test laboratory calibration are reference oils accepted by the ASTM Cummins Surveillance Panel. The standard deviations for the current reference oils for each parameter are presented below.

### Average Cam Shaft Wear

Unit of Measure: Micrometers

Prediction Error Monitoring and Severity Adjustment Parameter

|  |  |
| --- | --- |
| Reference Oil | Standard Deviation |
| 831 | 5.0 |
| 831-1 | 5.0 |

### Average Tappet Weight Loss

Unit of Measure: Milligrams

Prediction Error Monitoring and Severity Adjustment Parameter

|  |  |
| --- | --- |
| Reference Oil | Standard Deviation |
| 831 | 14.8 |
| 831-1 | 14.8 |

B. Monitoring and Adjustment Parameters

The constants used for the construction of the control charts for the Cummins ISB, and the adjustment and monitoring chart limits, are shown below.

Laboratory Shewhart Limits for Prediction Error Monitoring Parameters

|  |  |
| --- | --- |
| Shewhart Chart of Prediction Error ei = Yi – Zi-1 | |
| Limit Type | Limit |
| Level 3 | ±2.066 |
| Level 2 | ±1.734 |
| Level 1 | ±1.351 |

Laboratory EWMA Limits for Each Severity Adjustment Parameter

|  |  |  |  |
| --- | --- | --- | --- |
| EWMA of Standardized Test Result  Zi = λ(Yi) + (1 – λ)Zi-1 | | | |
| Limit Type | λ | ACSW Limit | ATWL Limit |
| Level 2  Upper Limit | 0.2 | 1.5 | 2.0 |
| Level 2  Lower Limit | 0.2 | -1.5 | -1.5 |
| Level 1 | 0.2 | 0 | 0 |

Severity Adjustment Standard Deviation for Each Severity Adjustment Parameter

|  |  |
| --- | --- |
| Severity Adjustment Parameter | Severity Adjustment Standard Deviation: sSA |
| ACWS | 5.0 |
| ATWL | 14.8 |

Laboratory Prediction Error and EWMA Reference Period Extension Limits for Each Reference Period Adjustment Parameter

|  |  |
| --- | --- |
| Limit Type | Limit |
| Ee | 1.05 |
| EZ | 0.66 |

Industry EWMA Limits for Each Severity Adjustment Parameter

|  |  |  |
| --- | --- | --- |
| EWMA of Standardized Test Result Zi = λ(Yi) + (1 – λ)Zi-1 | | |
| Limit Type | λ | Limit |
| Level 2  Upper Limit | 0.2 | 0.860 |
| Level 2  Lower Limit | 0.2 | -0.860 |
| Level 1 | 0.2 | ±0.653 |