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#### 4. Sequence IIIHB LTMS Requirements

The following are the specific IIIHB calibration test requirements.

##### A. Reference Oils and Critical Performance Criteria

The critical parameter is Phosphorous Retention. The reference oils required for test stand and test laboratory referencing are reference oils accepted by the ASTM Sequence III Surveillance Panel. The means and standard deviations for the current reference oils for each critical performance criterion are presented below.

#### PHOSPHOROUS RETENTION Unit of Measure: Percent

Reference Oil	Mean	Standard Deviation
434-2	79.95	1.58
434-3	79.95	1.58
436	94.15	2.02
438-1	78.92	1.54
438-2	78.92	1.54

##### B. Acceptance Criteria

###### 1. New Test Stands

- Stand must be calibrated according to Sequence IIIH requirements. A Sequence IIIHB test must be conducted as part of each Sequence IIIH test.
- A minimum of two (2) operationally valid calibration tests and/or matrix tests, with no Level 3 e<sub>i</sub> or level 2 Z<sub>i</sub> 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 Stands

6. Sequence IVB LTMS Requirements

The following are the specific Sequence IVB calibration test requirements.

A. Reference Oils and Critical Performance Criteria

The critical parameters are Average Volume Loss Intake Bucket Lifter (AVLI) and Iron at End of Test (FeWMEOT). The reference oils required for test stand and test laboratory referencing are reference oils accepted by the ASTM Sequence IVB Surveillance Panel. The means and standard deviations for the current reference oils for each critical performance criterion are presented below.

Average Volume Loss Intake Bucket Lifter  
Unit of Measure: sqrt(AVLI)

Reference Oil	Mean	Standard Deviation
300	1.3931	0.2230
1011	1.2538	0.1932
1011-1	1.2538	0.1847
1012	1.1543	0.1847

End of Test Iron  
Unit of Measure: ln(FeWMEOT)

Reference Oil	Mean	Standard Deviation
300	5.2645	0.3842
1011	5.0266	0.3508
1011-1	5.0266	0.3508
1012	4.8344	0.3747

A. Acceptance Criteria

1. New Test Stands

- A minimum of two (2) operationally valid calibration tests and/or matrix tests, with no Level 3 e<sub>i</sub> or level 2 Z<sub>i</sub> 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 Stands

- Previously calibrated test stands that have not run an acceptable reference test for two reference periods, may calibrate with one test provided  $e_i$  Level 1 limits are not exceeded. Otherwise a second test is required for calibration.
- Following the necessary tests, check the status of the control charts and follow the prescribed actions.

## 3. Reference Oil Assignment

Once test stands have been accepted into the system, the TMC will assign reference oils for continuing calibration according to the reference oil mix:

- Scheduled calibration tests should be conducted on reference oils 300, 1011, and 1012 or subsequent approved reblends in equal proportion with random assignment.

## 4. Control Charts

In Section 1, the construction of the control charts that constitute the Lubricant Test Monitoring System is outlined. For the Sequence IVB,  $Z_0 = \text{Mean } Y_i$  of first two operationally valid tests in the stand. The constants used for the construction of the control charts for the Sequence IVB, and the response necessary in the case of control chart limit alarms, are depicted below. Note that control charting all parameters is required.

### LUBRICANT TEST MONITORING SYSTEM CONSTANTS

		EWMA Chart		Stand Prediction Error	
		Severity		Severity	
Chart Level	Limit Type	Lambda	Alarm	Limit Type	Limit
Stand (AVLI)	Level 1	0.3	0.000	Level 1	$\pm 1.351$
	Level 2		$\pm 1.800$	Level 2	$\pm 1.734$
				Level 3	$\pm 2.066$
Stand (FeWMEOT)	Level 1	0.2	0.000	Level 1	$\pm 1.351$
	Level 2		$\pm 1.800$	Level 2	$\pm 1.734$
				Level 3	$\pm 2.066$
Industry	Level 1	0.2	$\pm 0.775$	--	--
	Level 2		$\pm 0.859$	--	--

## 8. Sequence IX LTMS Requirements

The following are the specific Sequence IX calibration test requirements.

### A. Reference Oils and Critical Performance Criteria

The critical performance criteria is Average Number of Preignitions (AVPIE). Additionally, an upper limit is set on Maximum Pre-ignition events. The reference oils required for test stand and test laboratory referencing are reference oils accepted by the ASTM Sequence IX Surveillance Panel. The means and standard deviations for the current reference oils for each critical performance criterion are presented below.

Average Number of Preignitions (AVPIE)  
Unit of Measure: Square Root (AVPIE+0.5)

Reference Oil	Mean	Standard Deviation
221	3.3819	0.3775
224	2.0445	0.3775
224-1	2.0445	0.3775
224-2	2.0445	0.3775

Maximum Number of Preignitions (MAXPIE)  
Unit of Measure: Square Root (MAXPIE+0.5)

Reference Oil	Targets
All Oils	N/A

### B. Acceptance Criteria

#### 1. New Test Stand/Engines

- A minimum of two (2) operationally valid calibration tests, with no Level 0  $e_i$  or Level 2  $Z_i$  alarms after the second operationally valid test must be conducted in a new stand-engine on any approved reference oils. If the above criteria cannot be met then a minimum of three (3) operationally valid calibration tests, with no Level 3  $e_i$  or level 2  $Z_i$  alarms after the third operationally valid test must be conducted in a new stand-engine on any approved reference oils.
- Additionally, engines using pistons other than BB grade pistons originally installed in the engine will be required to demonstrate discrimination by meeting the criteria of less than AVPIE of 2.12 for four consecutive valid iterations on RO220 (or subsequent reblends). These results will not be used for charting purposes.
- Following the necessary tests, check the status of the control charts and follow the prescribed actions.

## 2. Existing Test Stand/Engine

- The stand/engine must have previously been accepted into the system by meeting the LTMS requirements
- Existing test stand-engines that have run an acceptable reference in the past 180 days may calibrate with 1 test.
- Following the necessary tests, check the status of the control charts and follow the prescribed actions.

## 3. Reference Oil Assignment

Once test stand-engines have been accepted into the system, the TMC will assign reference oils for continuing calibration according to the reference oil mix:

- Scheduled calibration tests should be conducted on reference oils 221 and 224 or subsequent approved reblends in equal proportion with random assignment.

## 4. Control Charts

In Section 1, the construction of the control charts that contribute to the Lubricant Test Monitoring System is outlined. For the Sequence IX,  $Z_0 = \text{Mean } Y_i$  of all operationally valid tests in the initial stand-engine calibration sequence. The constants used for the construction of the control charts for the Sequence IX, and the response necessary in the case of control chart limit alarms, are depicted below.

### LUBRICANT TEST MONITORING SYSTEM CONSTANTS

		EWMA Chart		Stand-Engine Prediction Error	
		Severity		Severity	
Chart Level	Limit Type	Lambda	Alarm	Limit Type	Limit
Stand-Engine		0.4		Level 0	±1.000
	Level 1		0.000	Level 1	±1.351
	Level 2		±1.500	Level 2	±1.734
				Level 3	±2.066
Industry	Level 1	0.2	±0.775	-	-
	Level 2		±0.859	-	-

## 9. Sequence IX Aged Oil LSPI LTMS Requirements

The following are the specific Sequence IX Aged Oil LSPI calibration test requirements.

### A. Reference Oils and Critical Performance Criteria

The critical performance criteria is Average Number of Preignitions (AVPIE). The reference oils required for test stand and test laboratory referencing are reference oils accepted by the ASTM Sequence IX Surveillance Panel. The means and standard deviations for the current reference oils for each critical performance criterion are presented below.

Average Number of Preignitions (AVPIE)  
Unit of Measure: Square Root (AVPIE+0.5)

Reference Oil	Mean	Standard Deviation
API01	1.6280	0.4070
API01-1	1.6280	0.4070
API02	3.4085	0.4717
API02-1	3.4085	0.4717

### B. Acceptance Criteria

#### 1. New Aging Test Stands

- A minimum of two (2) operationally valid calibration tests, with no Shewhart alarms (preferably one on each oil) and no Level 2  $Z_i$  or  $E_i$  Level 3 alarms after the second operationally valid test must be conducted in a new Aging stand on any approved reference oils
- Following the necessary tests, check the status of the control charts and follow the prescribed actions.

#### 2. Existing Aging Test Stand

- The Aging stand must have previously been accepted into the system by meeting the LTMS requirements
- Existing test stands that have run an acceptable reference in the past 360 days may calibrate with 1 test.
- Following the necessary tests, check the status of the control charts and follow the prescribed actions.

#### 3. Reference Oil Assignment



Once Aging test stands have been accepted into the system, the TMC will assign reference oils for continuing calibration according to the reference oil mix:

- Scheduled calibration tests should be conducted on reference oils API01 and API02 or subsequent approved reblends in equal proportion with random assignment.

#### 4. Control Charts

In Section 1, the construction of the control charts that contribute to the Lubricant Test Monitoring System is outlined. For the Aged Oil LSPI,  $Z_0 = \text{Mean } Y_i$  of all operationally valid tests in the initial stand calibration sequence. The constants used for the construction of the control charts for the Sequence IX Aged, and the response necessary in the case of control chart limit alarms, are depicted below.

#### LUBRICANT TEST MONITORING SYSTEM CONSTANTS

		EWMA Chart		Stand Prediction Error		Shewhart
		Severity		Severity		Severity
Chart Level	Limit Type	Lambda	Alarm	Limit Type	Limit	Limit
	Level 1	0.2		Level 1	±1.351	±2.000
	Level 2		±1.300	Level 2	±1.734	
				Level 3	±2.066	
Industry	Level 1	0.2	±0.775	--	-	N/A
	Level 2		±0.859	-	-	

Sequence IIIHB Reference Oil Targets					
Oil	n	Effective Dates		Phosphorus Retention %	
		From <sup>1</sup>	To <sup>2</sup>	$\bar{X}$	s
434-2 <sup>3</sup>	10	07-01-15	***	79.95	1.58
434-3	10	07-01-15	***	79.95	1.58
436 <sup>3</sup>	9	07-01-15	***	94.15	2.02
438-1 <sup>3</sup>	9	04-01-15	***	78.92	1.54
438-2	9	09-01-19	***	78.92	1.54

- 1 Effective for all tests completed on or after this date
- 2 \*\*\* = Currently in effect
- 3 Targets based on precision matrix analysis

Sequence IVB Oil Targets							
Oil	n	Effective Dates		AVLI		FeWMEOT	
		From <sup>1</sup>	To <sup>2</sup>	$\bar{X}$	s	$\bar{X}$	s
300	9	10-27-17	***	1.3931	0.2230	5.2645	0.3842
300-1	9	03-04-19	***	1.3931	0.2230	5.2645	0.3842
1011	9	10-27-17	***	1.2538	0.1932	5.0266	0.3508
1011-1	9	11-25-21	***	1.2538	0.1932	5.0266	0.3508
1012	10	10-27-17	***	1.1543	0.1847	4.8344	0.3747

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

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

Sequence IX Oil Targets					
Oil	n	Effective Dates		AVGPIE	
		From <sup>1</sup>	To <sup>2</sup>	$\bar{X}$	s <sup>3</sup>
221	8 <sup>4</sup>	4-21-17	6-27-19	3.3819	0.3609
221	8 <sup>4</sup>	6-28-19	***	3.3819	0.3775
222	16 <sup>4</sup>	4-21-17	***	4.2644	0.2694
224	9	6-28-19	***	2.0445	0.3775
224-1	9	5-1-23	***	2.0445	0.3775
224-2	9	8-9-24	***	2.0445	0.3775

- 1 Effective for all tests completed on or after this date.
- 2 \*\*\* = currently in effect.
- 3 Pooled s from matrix analysis.
- 4 Matrix + additional tests n-size.

Aged Oil LSPI Oil Targets					
Oil	n	Effective Dates		Average Number of Pre-Ignitions Sqrt (AVPIE+0.5)	
		From <sup>1</sup>	To <sup>2</sup>	$\bar{X}$	s
API01	12	2-15-2022	***	1.628	0.4070
API01-1	12	8-27-2024	***	1.628	0.4070
API02	12	2-15-2022	***	3.4085	0.4717
API02-1	12	6-8-2024	***	3.4085	0.4717

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

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