2. Shewhart Chart for Monitoring Precision

The vertical axis of this control chart represents the standardized calibration test moving ranges (R). These results are plotted against completion date order (integer) which is on the horizontal axis. R is calculated as follows:

$$R_i = \frac{\sqrt{|Y_i - Y_{i-1}|} - 0.969}{0.416}$$

R_i = Standardized test moving range at test order i. (For Sequence VID, $R_1 = 0$)

where: $Y_0 = 0$

The following is the control chart limit for the Shewhart chart for monitoring precision (R plotted against completion date order).

$0 + K$

K is a constant that determines the chart's estimated false detection rate. Deterioration in precision is signaled by control chart points exceeding the value of K. K is test type specific.

3. Exponentially Weighted Moving Average (EWMA) Chart for Monitoring Severity

The vertical axis of this control chart represents the EWMA of standardized calibration test results (Z). These results are plotted against completion date order (integer) which is on the horizontal axis. Z is calculated as follows:

Z_i = EWMA of the standardized test result at test order i.

Z_i = (LAMBDA) Y_i + (1 - LAMBDA) Z_{i-1}

where: $0 \leq$ LAMBDA ≤ 1,
$Z_0 = 0$ (An alternate, fast start Z_0 could be indicated for a specific test. Section 4.0 under the specific test area will denote this option)

LAMBDA (λ) is the smoothing constant and must be between 0 and 1. This value determines the amount of weight given to the current and past data points. As LAMBDA decreases, past data points are given more weight and the resulting plot gets smoother. When LAMBDA is set equal to 1, the EWMA chart is equivalent to the Shewhart chart.

The following are the control chart limits for the EWMA chart for monitoring severity (Z plotted against completion date order).

$$0 \pm K\sqrt{\frac{\lambda}{2 - \lambda}}$$

K is a constant that determines the chart's estimated false detection rate. K is test type specific.

c. The first (3) tests must be conducted on reference oils 542 (GF5X), 541 (GF5D) and 1010, in that order for new engine reference acceptance. When 541 is not available, 540 may be used instead of 541.

2. Existing Test Stand/Engine

   a. The stand/engine must have previously been accepted into the system by meeting the LTMS requirements

   b. All operationally valid tests must be charted to determine if the stand/engine is in control as defined by the control charts in the Lubricant Test Monitoring System. If there are two (2) or more operationally invalid tests during the attempt to calibrate an existing stand/engine, then two (2) operationally valid calibration tests, with no Shewhart severity alarms (all parameters), are required to calibrate the stand/engine.

3. Reference Oil Assignment:

   a. For new stand/engines, see Section 1.c above.

   b. Once a stand/engine has been accepted into the system, 100% of the scheduled calibration tests should be conducted on reference oils 540, 542, and 1010 or subsequent approved reblends. If possible, the same oil should not be used for successive calibration tests in a stand.

4. Control Charts

In Section 1, the construction of the control charts that contribute to the Lubricant Test Monitoring System is outlined. Z_0=Mean Y_i of first three operationally valid calibration tests in a stand/engine. The constants used for the construction of the control charts for the VID, and the response necessary in the case of control chart limit alarms, are depicted below. *Note that laboratory control charts are only updated following an acceptable stand/engine calibration test.*

LUBRICANT TEST MONITORING SYSTEM CONSTANTS

| Chart Level | Limit Type | EWMA Chart | | | | Shewhart Chart | |
| | | LAMBDA | | K | | K | |
		Precision	Severity	Precision	Severity	Precision	Severity
Stand/Engine	Special K	--	--	--	--	--	2.96
	Warning	--	--	--	--	1.645	
	Action	0.1	0.3	1.645	0.000	2.325	1.96
Industry	Warning	0.1	0.2	1.645	1.96	--	--
	Action	0.1	0.2	2.33	2.575	--	--

- Exceed Laboratory chart of Prediction Error (e_i)

    Level 3:

    – Immediately conduct one additional reference test in the stand that triggered the alarm. Do not update the control charts until the follow up reference test is completed and the Excessive Influence (refer to Section 1.A.5) has been performed.

    Level 2:

    – The Level 2 limit applies in situations that have been pre-determined by the surveillance panel to have a potential impact on test results. These situations may include the introduction of new critical parts, fuel batches, reference oil reblends, or other test components. When these conditions have been met and a Level 2 alarm is triggered, immediately conduct one additional reference test in the stand that triggered the alarm.

    Level 1:
    – The Level 1 limit also applies to 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.

- Exceed Engine – Stand EWMA of Standardized Test Result (Z_i)

    Level 2:

    – Immediately conduct one additional reference test in the engine-stand that triggered the alarm. The engine-stand that triggered the alarm is not qualified for non-reference tests until the Level 2 alarm is cleared.
    – In instances where surveillance panel has deemed that industry-wide circumstances are impacting the Level 2 alarm, the TMC may be asked to review engine-stand calibration status in accordance with the surveillance panel's findings.

    Level 1:

    – The Level 1 limit applies to all reference tests that are control charted, even when other alarms have been triggered. Level 1 uses Z_i to determine the engine-stand severity adjustment (SA). Calculate the engine-stand SA as follows and confirm the calculation with the TMC:

    IR Oxidation Peak Height at 360 hours: $SA = (-Z_i) \times (11.1)$
    Percent Increase in Viscosity at 40°C from 300 to 360 hour: $SA = (-Z_i) \times (0.929)$

24. Roller Follower Wear Test LTMS Requirements

The following are the specific Roller Follower Wear Test calibration requirements.

A. Reference Oils and Critical Parameter

The critical parameter is Average Roller Follower Shaft Wear. The reference oils required for test stand and test laboratory calibration are reference oils accepted by the Roller Follower Wear Test Surveillance Panel. The means and standard deviations for the current reference oils for the critical parameter are presented below.

AVERAGE ROLLER FOLLOWER SHAFT WEAR
Unit of Measure: mils

Reference Oil	Mean	Standard Deviation
1004-2	0.33	0.05
1004-3	0.44	0.06
1005-3	0.20	0.05
1005-4	0.20	0.05
1005-5	0.20	0.05

B. Acceptance Criteria

1. New Test Stand

- A minimum of two (2) operationally valid calibration tests with no stand Shewhart severity or precision alarms must be conducted on any approved reference oil.

- 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 previously been accepted into the system by meeting LTMS calibration requirements.

- All operationally valid calibration test results on reference oils 1004 and 1005, or subsequent approved reblends, 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.

Roller Follower Wear Test Reference Oil Targets						
Engine Type	Oil	n	Effective Dates		Average Wear	
			From[1]	To[2]	$\overline{X}$	s
6.2L	1004	15	5-27-93	5-31-96	0.40	0.08
	1004-1	--	2-1-94	10-16-94	0.40	0.08
		10	10-17-94	6-25-95	0.36	0.05
		21	6-26-95	5-31-96	0.35	0.04
	1004-2[3]	--	9-1-95	5-31-96	0.35	0.04
6.5L	1004-1	--	6-1-96	***	0.35	0.06[5]
	1004-2	--	6-1-96	12-31-97	0.35[4]	0.06[5]
		10	1-1-98	***	0.33	0.05
	1004-3	2	1-1-98	***	0.44	0.06
	1005	2	6-1-96	5-24-97	0.20	0.06
		4	5-25-97	8-11-97	0.19	0.06
		6	8-12-97	***	0.20	0.06
	1005-1[6]	--	5-1-98	10-31-00	0.20	0.06
		5	11-1-00	***	0.20	0.05[7]
	1005-2[8]	--	11-1-00	***	0.20	0.05
	1005-3[8]	--	08-20-10	***	0.20	0.05
	1005-4[8]	--	10-00-13	***	0.20	0.05
	1005-5[8]	--	02-18-16	***	0.20	0.05

1   Effective for all tests completed on or after this date.
2   *** = currently in effect.
3   Targets based on 1004-1.
4   Mean based on 1004-1.
5   Standard deviation based on all 6.2L results on all blends of 1004 through 5-31-96 (n=45).
6   Targets based on 1005.
7   Pooled standard deviation for all Roller Follower Wear reference oil tests through 10-12-00.
8   Targets based on 1005-1.

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

Test	Parameter	s	Effective Dates	
			From	To
T-8	Vis. Inc. @ 3.8%	1.19	19940401	19960930
	Vis. Inc. @ 3.8%	0.93	19961001	19990131
	Vis. Inc. @ 3.8%	0.90	19990201	20070524
	Vis. Inc. @ 3.8%	0.00	20070525	20110916
	Vis. Inc. @ 3.8%	0.56	20110917	***
T-8E	Rel. Vis. @ 4.8% 50% DIN Shear	0.26	19970127	20070524
	Rel. Vis. @ 4.8% 50% DIN Shear	0.00	20070525	20110916
	Rel. Vis. @ 4.8% 50% DIN Shear	0.08	20110917	***
	Rel. Vis. @ 4.8% 100% DIN Shear	0.27	20020306	20070524
	Rel. Vis. @ 4.8% 100% DIN Shear	0.00	20070525	20110916
	Rel. Vis. @ 4.8% 100% DIN Shear	0.09	20110917	***
T-10A	MRV Viscosity	511	20001201	20020115
		643	20020116	20020924
		496	20020925	20030121
		497	20030122	***
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	***
T-12	Cyl. Liner Wear	1.6	20050219	***
	Top Ring Wt. Loss	24.9	20050219	***
	Oil Consumption	0.0610	20050219	***
	ΔPB @ EOT	0.2880	20050219	***
	ΔPB 250-300 h	0.3630	20050219	***
	Cyl. Liner Wear	1.6	20050219	***
	Top Ring Wt. Loss	24.9	20050219	***
	Oil Consumption	0.0610	20050219	***
	ΔPB @ EOT	0.2880	20050219	***
	ΔPB 250-300 h	0.3630	20050219	***
T13	IRPH	12.4	20141001	20160127
	%KV40[1]	1.212	20141001	20160127
	IRPH	11.1	20160128	***
	%KV40[1]	0.929	20160128	***

1   SQRT Transformation adopted 20151019