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MEMORANDUM: 03-011

DATE: February 7, 2003

TO: L-37 Surveillance Panel

FROM: Frank M. Farber

SUBJECT: Rater Calibration Monitoring System

On January 29, 2003 the L-37 Surveillance Panel approved the ASTM Test Monitoring Center (TMC) to administer a rater calibration monitoring system. The monitoring system is detailed in the attached document.

The attached document is posted on the TMC website at the following location: ftp://ftp.astmtmc.cmu.edu/docs/rater_calibration/

FMF/fmf

Attachment

c: ftp://ftp.astmtmc.cmu.edu/docs/gears/l37/memos/mem03-011.pdf
TMC Engineers

Distribution: Email

RATER CALIBRATION MONITORING SYSTEM

ASTM Test Monitoring Center
Requirements for Rater Calibration

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2/10/2003

Acknowledgment

The Rater Calibration Monitoring System (RCMS) described in this document is the result of efforts of the ASTM L-37 Surveillance Panel. The panel applied a logical and data based analytical approach to available ASTM rater calibration test data in the development of the RCMS. This system of managing rater calibration for severity (bias) and precision was presented to the ASTM L-37 Surveillance Panel in January, 2003 by the ASTM TMC.

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1. Rater Calibration Monitoring System Control Charts

Raters are calibrated by the ASTM Test Monitoring Center (TMC). Calibration is in terms of both test severity and precision and is checked by the application of the control charts in the Rater Calibration Monitoring System (RCMS). The purpose of the control charts is to monitor and track both large abrupt changes and smaller consistent trends in both rating severity and precision. The Shewhart charts check for the abrupt changes while the Exponentially Weighted Moving Average (EWMA) charts check for consistent changes and trends over time. The four control charts are listed below:

1. Shewhart Chart for Monitoring Severity
2. Shewhart Chart for Monitoring Precision
3. EWMA Chart for Monitoring Severity
4. EWMA Chart for Monitoring Precision

A. Control Chart Construction

This section outlines the construction of the four control charts that constitute this Rater Calibration Monitoring System. An example is provided in Exhibit I.

1. Shewhart Chart for Monitoring Severity

The vertical axis of this control chart represents the average (M) of four standardized rating results (Y). These results are plotted against count in completion date order on the horizontal axis. Y is calculated as follows:

$$Y_i = \frac{T_i - \text{Segment MEAN}}{\text{Segment STANDARD DEVIATION}}$$

T_i = Rating result at order i in appropriate units (see applicable test type in Section 2).

M_i = Average of the four standardized rating results at order i.

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

$$0 \pm \frac{K}{\sqrt{n}}$$

K is a constant that determines the chart's estimated false detection rate. The false detection rate is the percentage of time that a plotted result will fall outside the control limits when, in fact, no change in the process has occurred. As K increases, the false detection rate decreases. However, the false detection rate must be balanced with the chart's sensitivity to real changes in the process. This sensitivity is diminished as K increases. K is test type specific. n is a constant that is based on the number of parts rated. For the L-37 this n = 4.

2. Shewhart Chart for Monitoring Precision

The vertical axis of this control chart represents the standardized natural log of the standard deviation of the four results (R). These results are plotted against completion date order (integer) which is on the horizontal axis. R is calculated as follows:

$$Ri = \left[\frac{\ln(Ni) + 0.1838}{0.4855} \right]$$

R_i = Standardized natural log of the standard deviation of the four results at order i.
N_i = Is the standard deviation of the Δ/s values (Y) for the four rating results.

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 the average of four standardized rating 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 average of four standardized individual segment results at result order i.

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

where: $0 \leq \text{LAMBDA} \leq 1$,
$Z_0 = 0$

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 value of Z at result order 0, Z_0, must be set equal to 0.

The following are the control chart limits for the EWMA chart for monitoring severity (Z plotted

$$0 \pm \frac{K}{\sqrt{n}} \left(\sqrt{\frac{\lambda}{2 - \lambda}} \right)$$

against completion date order).

K is a constant that determines the chart's estimated false detection rate. K is test type specific. n is the number of parts rated. For the L-37, n=4.

4. EWMA Chart for Monitoring Precision

The vertical axis of this control chart represents the EWMA of standardized natural log of the standard deviation of the four results (Q).). These results are plotted against completion date order (integer). Q is calculated as follows:

Q_i = (LAMBDA) R_i + (1 - LAMBDA) Q_{i-1}

where: $0 \leq \text{LAMBDA} \leq 1$, $Q_0 = 0$

Q_i = EWMA of standardized natural log of the standard deviation of the four results at test order i.

LAMBDA (λ) is the smoothing constant and must be between 0 and 1. The value Q at result order 0, Q_0, must be set equal to 0.

The following is the control chart limit for the EWMA chart for monitoring precision (Q 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.

EXHIBIT I: Example of Control Charts
Sequence L-37 Wear Data

Calibration Cycle	Segment	Pinion ID	Rating Result	Transformed Rating Result (Ti)	Target		Yi	Average Yi (Mi)	EWMA Severity (Zi)	Std of Yi's (Ni)	Ri	Qi
					Pinion Mean	Pinion Std						
1	A	8	7	7	7.6	1.09	-0.5505	-0.6881	-0.1376	0.4270	-1.3742	-0.2749
	B	10	5	5	5.9	1.09	-0.8257					
	C	24	8	8	8.2	1.09	-0.1835					
	D	26	8	8	9.3	1.09	-1.1927					
2	A	6	8	8	7.1	1.09	0.8257	0.4358	-0.0229	0.3463	-1.8058	-0.5810
	B	12	7	7	7	1.09	0.0000					
	C	25	8	8	7.6	1.09	0.3670					
	D	27	9	9	8.4	1.09	0.5505					
3	A	2	7	7	8.1	1.09	-1.0092	-0.1376	-0.0459	1.1761	0.7126	-0.3223
	B	3	5	5	6.4	1.09	-1.2844					
	C	13	10	10	9.2	1.09	0.7339					
	D	30	5	5	3.9	1.09	1.0092					

Shewhart Chart for Monitoring Severity: K=1.8
Shewhart Chart for Monitoring Precision: K=2.1
EWMA Chart for Monitoring Severity: K=1.96 LAMBDA=0.2
EWMA Chart for Monitoring Precision: K=2.1 LAMBDA=0.2

B. Engineering Judgment as Applied to the Interpretation of RCMS Control Charts

The Rater Calibration Monitoring System (RCMS) Shewhart and EWMA control charts, by design, will infrequently produce false indications of the severity and/or precision of a rating result. One type of false indication is an alarm that is not the result of a real problem but is, rather, an anomaly. A second type of false indication occurs when a real problem exists, yet the control charts remain within acceptable limits. On occasion, when sufficient technical information is available, either type of false indication can be identified as such. In these cases, the ASTM Test Monitoring Center (TMC), through the application of engineering judgment, may determine that a deviation from normal RCMS actions is warranted. The following points describe the process by which engineering judgment is applied by the TMC:

1. The TMC determines if the potential exists for the application of engineering judgment in the interpretation of control charts.

2. When it is determined that the potential exists for the application of engineering judgment, all subsequent investigation proceeds under the assumption that the current control chart indications are correct.

3. When an engineering investigation is commenced, it is incumbent on the affected rater to prepare necessary technical information in concert with the TMC.

4. The TMC may solicit relevant input from outside sources, such as the Test Developer, Surveillance Panel Chairman, O&H Subpanel Leader and ASTM rating workshop chairman. In all cases, the confidentiality of the affected rater will be appropriately maintained.

5. If, in the judgment of the TMC, a deviation from normal RCMS actions is warranted, this judgment will be documented in writing along with a summary of the relevant technical information considered in making the judgment. The affected rater will receive copies of this document.

6. If, in the judgment of the TMC, normal RCMS action should be followed by the affected rater, no special documentation is required.

7. The application of engineering judgment in the interpretation of RCMS control charts is handled on a case-by-case basis. The TMC does not consider any prior judgment rendered to be precedent setting.

C. TMC Notification Requirement

In order to allow time for shipment of parts, it is the responsibility of the test lab to schedule a rater calibration with the TMC at least 14 working days prior to expiration of the rater's calibration period. The TMC will transmit an analysis confirmation to the lab contact(s) after reviewing the results.

D. Hardware Monitoring & New Hardware Introduction

The TMC is responsible for monitoring hardware to track possible severity changes over-time. This monitoring will occur each time a part is rated. Upon request the TMC will provide a severity plot of individual hardware to assess possible changes with time. Hardware may be removed from the system when sufficient cause is documented.

New hardware that is intended for introduction into the system must be rated by experienced in-control industry raters so that consensus targets are obtained. The TMC will facilitate this process with direction from the L-37 Surveillance Panel. In order, to ease the burden of raters participating in this function every attempt will be made to minimize the frequency of the activity.

E. Rater Training/Review

A rater may seek training to understand problem areas and determine corrective action. The matter of training is an internal laboratory issue that various labs may choose to handle differently. For example, in-house raters may be used for consultation, a rater may attend an upcoming rater workshop or other laboratory raters may be brought in-house or visited. Documentation of the training event is to be provided to the TMC with any calibration request after an alarm. After a training event, engineering judgment may be used to ensure that control charting accurately reflects the rater's performance.

2. L-37 RCMS Requirements

The following are the specific L-37 rater calibration requirements.

A. Parameters

The critical parameters are Pinion Wear, Rippling, Ridging, and Spalling/Pitting ("Spitting"). The means and standard deviations for the parts for each critical parameter are presented below.

PINION WEAR

Pinion Id	Severity Targets Unit of Measure: WEAR MERITS	
	Mean	Standard Deviation
1	5.9	1.0000
2	6.6	0.6666
3	6.6	0.6666
4	7.2	0.8888
5	6.6	0.6666
6	6.2	0.8888
7	7.8	0.8888
8	7.7	0.7777
9	6.1	1.000
10	5.7	0.7777
11	6.9	1.000
12	3.4	0.6666
13	8.2	0.8888
14	6.7	0.7777
15	5.4	0.6666
16	8.2	0.8888
17	6.0	1.1111
18	5.7	0.7777
19	7.0	1.1111
20	Removed from system	
21	6.0	1.1111
22	7.3	0.7777
23	Removed from system	
24	5.6	0.6666
25	6.7	0.7777
26	8.8	0.8888
27	5.7	0.7777
28	6.2	0.8888
29	7.7	0.7777
30	7.0	1.0000

PINION RIPPLING

Pinion Id	Severity Targets Unit of Measure: RIPPLING MERITS	
	Mean	Standard Deviation
1	7.8	0.8888
2	8.1	1.2222
3	6.4	0.6666
4	9.1	1.0000
5	9.1	1.2222
6	7.1	1.0000
7	8.6	0.6666
8	7.6	0.6666
9	8.7	0.7777
10	5.9	1.0000
11	6.9	1.0000
12	7.0	1.1111
13	9.2	0.8888
14	9.0	1.1111
15	8.6	0.6666
16	9.6	0.6666
17	8.6	0.6666
18	9.0	1.1111
19	9.6	0.6666
20	Removed from system	
21	9.2	0.8888
22	9.0	1.0000
23	Removed from system	
24	8.2	0.8888
25	7.6	0.6666
26	9.3	0.7777
27	8.4	0.6666
28	8.3	0.7777
29	9.6	0.6666
30	3.9	1.0000

PINION RIDGING

Pinion Id	Severity Targets Unit of Measure: RIDGING MERITS	
	Mean	Standard Deviation
1	5.4	0.6666
2	8.4	0.6666
3	7.6	1.5555
4	9.2	0.8888
5	8.2	0.8888
6	6.1	1.0000
7	9.2	0.8888
8	7.9	1.0000
9	7.8	0.8888
10	8.3	0.7777
11	8.4	0.6666
12	4.6	0.6666
13	9.9	1.0000
14	6.7	1.4444
15	5.6	0.6666
16	9.6	0.6666
17	7.4	0.6666
18	4.8	0.8888
19	7.6	0.6666
20	Removed from system	
21	8.2	0.8888
22	8.9	1.1111
23	Removed from system	
24	7.4	0.6666
25	8.1	1.0000
26	9.8	0.8888
27	5.6	0.6666
28	7.4	0.6666
29	9.7	0.7777
30	8.9	1.0000

PINION SPALLING/PITTING (“SPITTING”)

Pinion Id	Severity Targets Unit of Measure: SPITTING MERITS	
	Mean	Standard Deviation
1	9.91	0.1000
2	9.54	0.2888
3	9.86	0.0666
4	9.87	0.0777
5	6.89	0.9888
6	9.91	0.1000
7	9.87	0.0777
8	9.91	0.1000
9	9.67	0.1888
10	9.86	0.0666
11	9.58	0.1333
12	5.44	0.6222
13	9.97	0.0777
14	9.86	0.0666
15	7.56	0.6222
16	9.97	0.0777
17	5.78	0.8666
18	9.88	0.0889
19	9.92	0.0888
20	Removed from system	
21	8.00	1.0000
22	9.90	0.0999
23	Removed from system	
24	2.50	0.5555
25	9.90	0.1111
26	9.98	0.0888
27	9.80	0.1111
28	9.58	0.1333
29	9.93	0.0777
30	9.87	0.1444

B. Acceptance Criteria

1. New Rater

- A minimum of 2 groups of four (4) pinion ratings, with no Shewhart severity or precision alarms after the last rating

- All ratings results must be charted to determine if the rater is currently "in control" as defined by the control charts from the Rater Calibration Monitoring System. Note, that non-lubrited and lubrited hardware rating results are charted together.

2. Existing Rater

- The rater must have previously been accepted into the system by meeting RCMS calibration requirements.

- All ratings results must be charted to determine if the rater is currently "in control" as defined by the control charts from the Rater Calibration Monitoring System. Note, that non-lubrited and lubrited hardware rating results are charted together.

3. Rating Calibration Frequency

Once raters have been accepted into the system, the TMC will conduct rating calibration cycles for continuing calibration utilizing the following hardware :

Rating Hardware	Pinion Batch
Non-lubrited	C1L308
	C1L426
	V1L303
	V1L686
Lubrited	C1L308
	C1L426
	V1L303

A calibration cycle consists of a rater rating four pinions. Only one tooth on the pinion is to be rated as marked by the TMC. The results are to be returned to the TMC for analysis.

4. Control Charts

In Section 1, the construction of the four (4) control charts that constitute the Rating Calibration Monitoring System is outlined. The constants used for the construction of the control charts for the L-37, and the response necessary in the case of control chart limit alarms, are depicted below. Note that control charting all parameters is required.

RATER CALIBRATION MONITORING SYSTEM CONSTANTS

		EWMA Chart				Shewhart Chart	
		LAMBDA		K		K	
Chart Level	Limit Type	Precision	Severity	Precision	Severity	Precision	Severity
Rater	Action	0.2	0.2	2.1	1.96	2.1	1.80

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

- Exceed EWMA limit for precision
  - Rater is not calibrated. Request additional pinions from TMC.
- Exceed Shewhart limit for precision
  - Rater is not calibrated. Request additional pinions from TMC.
- Exceed Shewhart limit for severity

- Rater is not calibrated. Request additional pinions from TMC.

- Exceed *only* EWMA limit for severity

  - Rater is calibrated for a period of 3 months. Upon the fourth consecutive alarm, the rater is no longer calibrated. The rater is to complete a documented training exercise before re-testing is allowed.

- No alarms

  - Rater is calibrated for a period of 6 months.

APPENDIX A

HISTORY OF RCMS PARTS MEANS
AND STANDARD DEVIATIONS

L-37 Rating Calibration Targets[1]											
		Effective Dates		Wear		Rippling		Ridging		Spitting	
Pinion	n	From	To	$\overline{X}$	s	$\overline{X}$	s	$\overline{X}$	s	$\overline{X}$	s
1	9	19010101	99999999	5.9	1.0000	7.8	0.8888	5.4	0.6666	9.91	0.1000
2	9	19010101	99999999	6.6	0.6666	8.1	1.2222	8.4	0.6666	9.54	0.2888
3	9	19010101	99999999	6.6	0.6666	6.4	0.6666	7.6	1.5555	9.86	0.0666
4	9	19010101	99999999	7.2	0.8888	9.1	1.0000	9.2	0.8888	9.87	0.0777
5	9	19010101	99999999	6.6	0.6666	9.1	1.2222	8.2	0.8888	6.89	0.9888
6	9	19010101	99999999	6.2	0.8888	7.1	1.0000	6.1	1.0000	9.91	0.1000
7	9	19010101	99999999	7.8	0.8888	8.6	0.6666	9.2	0.8888	9.87	0.0777
8	9	19010101	99999999	7.7	0.7777	7.6	0.6666	7.9	1.0000	9.91	0.1000
9	9	19010101	99999999	6.1	1.0000	8.7	0.7777	7.8	0.8888	9.67	0.1888
10	9	19010101	99999999	5.7	0.7777	5.9	1.0000	8.3	0.7777	9.86	0.0666
11	9	19010101	99999999	6.9	1.0000	6.9	1.0000	8.4	0.6666	9.58	0.1333
12	9	19010101	99999999	3.4	0.6666	7.0	1.1111	4.6	0.6666	5.44	0.6222
13	9	19010101	99999999	8.2	0.8888	9.2	0.8888	9.9	1.0000	9.97	0.0777
14	9	19010101	99999999	6.7	0.7777	9.0	1.1111	6.7	1.4444	9.86	0.0666
15	9	19010101	99999999	5.4	0.6666	8.6	0.6666	5.6	0.6666	7.56	0.6222
16	9	19010101	99999999	8.2	0.8888	9.6	0.6666	9.6	0.6666	9.97	0.0777
17	9	19010101	99999999	6.0	1.1111	8.6	0.6666	7.4	0.6666	5.78	0.8666
18	9	19010101	99999999	5.7	0.7777	9.0	1.1111	4.8	0.8888	9.88	0.0889
19	9	19010101	99999999	7.0	1.1111	9.6	0.6666	7.6	0.6666	9.92	0.0888
21	9	19010101	99999999	6.0	1.1111	9.2	0.8888	8.2	0.8888	8.00	1.0000
22	9	19010101	99999999	7.3	0.7777	9.0	1.0000	8.9	1.1111	9.90	0.0999
24	9	19010101	99999999	5.6	0.6666	8.2	0.8888	7.4	0.6666	2.50	0.5555
25	9	19010101	99999999	6.7	0.7777	7.6	0.6666	8.1	1.0000	9.90	0.1111
26	9	19010101	99999999	8.8	0.8888	9.3	0.7777	9.8	0.8888	9.98	0.0888
27	9	19010101	99999999	5.7	0.7777	8.4	0.6666	5.6	0.6666	9.80	0.1111
28	9	19010101	99999999	6.2	0.8888	8.3	0.7777	7.4	0.6666	9.58	0.1333
29	9	19010101	99999999	7.7	0.7777	9.6	0.6666	9.7	0.7777	9.93	0.0777
30	9	19010101	99999999	7.0	1.1111	3.9	1.0000	8.9	1.0000	9.87	0.1444

[1] Targets are rater consensus derived. Standard deviations have been back calculated to ensure acceptable acceptance limits.