Test Monitoring Center
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Memorandum: 01-051

Date: May 9, 2001

To: Larry M. Bendele, Chairman, Sequence IVA Surveillance Panel

From: Michael T. Kasimirsky

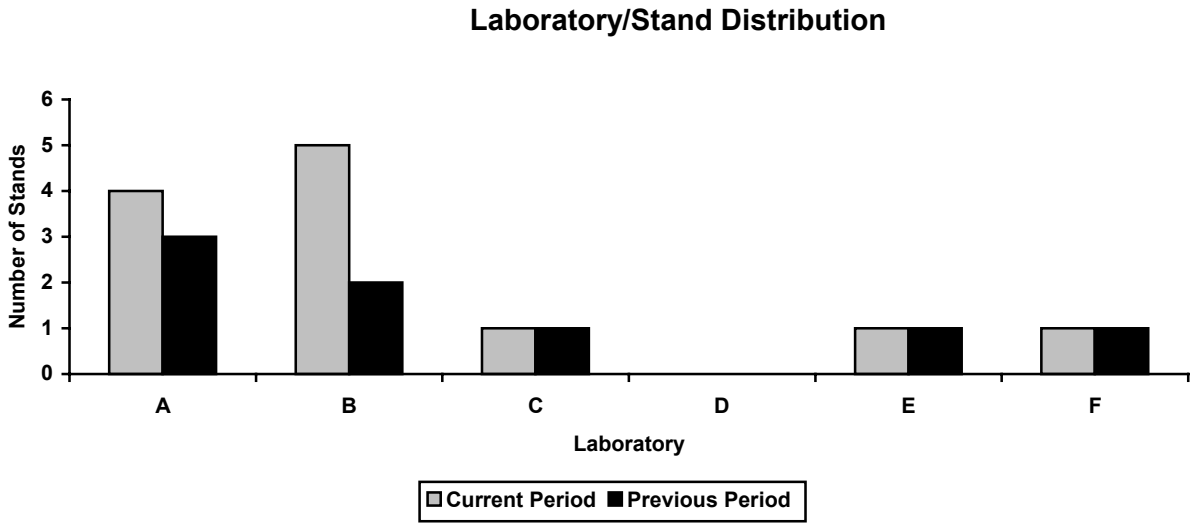
Subject: Sequence IVA Semiannual Report: October 1, 2000 through March 31, 2001

The following is a summary of Sequence IVA reference tests that were reported to the Test Monitoring Center during the period October 1, 2000 through March 31, 2001.

Lab/Stand Distribution

	Reporting Data	Calibrated as of March 31, 2001
Number of Laboratories:	5	4
Number of Test Stands:	12	8

The following chart shows the laboratory/stand distribution:

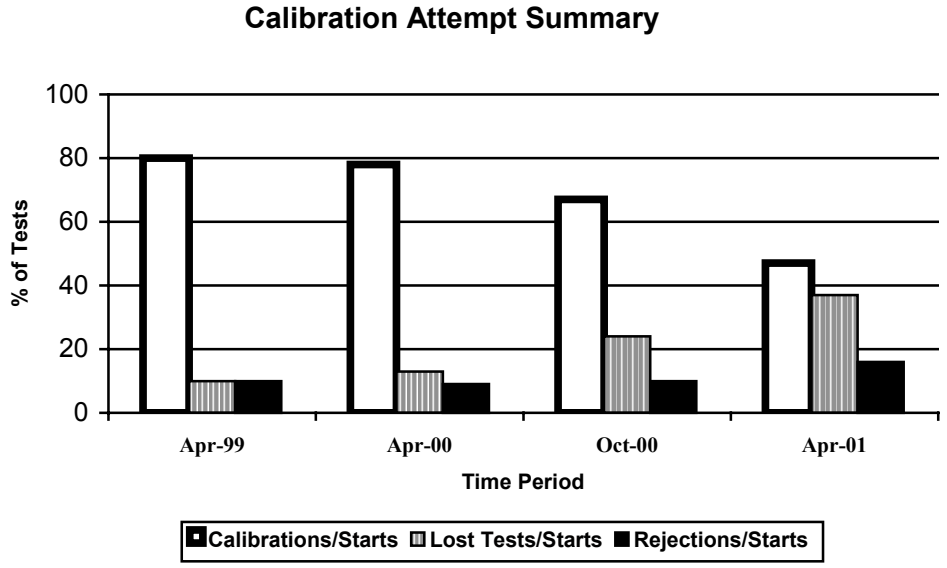


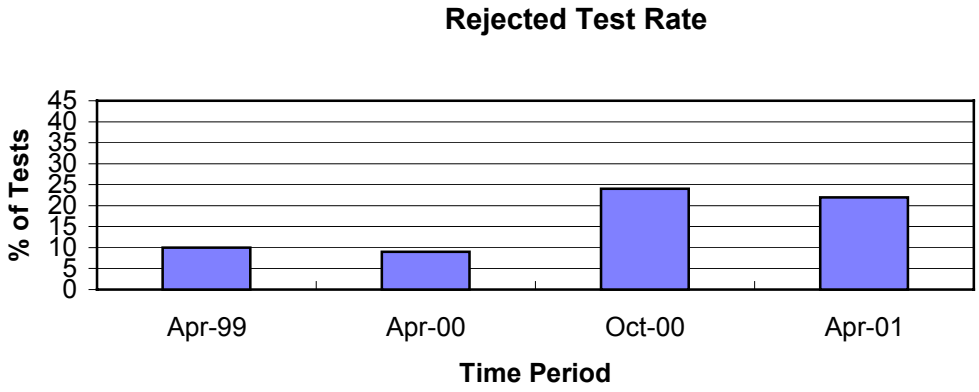
The following summarizes the status of the reference oil tests reported to the TMC:

Calibration Start Outcomes	TMC Validity Codes	No. of Tests
Operationally and Statistically Acceptable	AC	24
Failed Acceptance Criteria	OC	8
Stand Failed Reference Sequence – data pulled	MC	5
Operationally Invalid (Laboratory Judgment)	LC	10
Operationally Invalid (Lab & TMC Judgment)	RC	0
Aborted	XC	4
Total		51

Donated & Industry Support Outcomes	TMC Validity Codes	No. of Tests
Acceptable Decoded Runs	AG	1
Unacceptable Decoded Runs	OG	4
Invalid Decoded Runs	LG	0
Total		5

Calibrations per start, lost tests per start and rejection rates are summarized below:





There were eight failing tests for the period; six failed due to Shewhart Severity alarms on ACW. Two were in the mild direction and four in the severe direction. One test failed due to Shewhart Precision Alarms at both the stand and lab level. The final failing test was due to an EWMA Precision Alarm at the stand level, an EWMA Precision Warning at the lab level, and Shewhart Precision Alarms at both the lab and stand level.

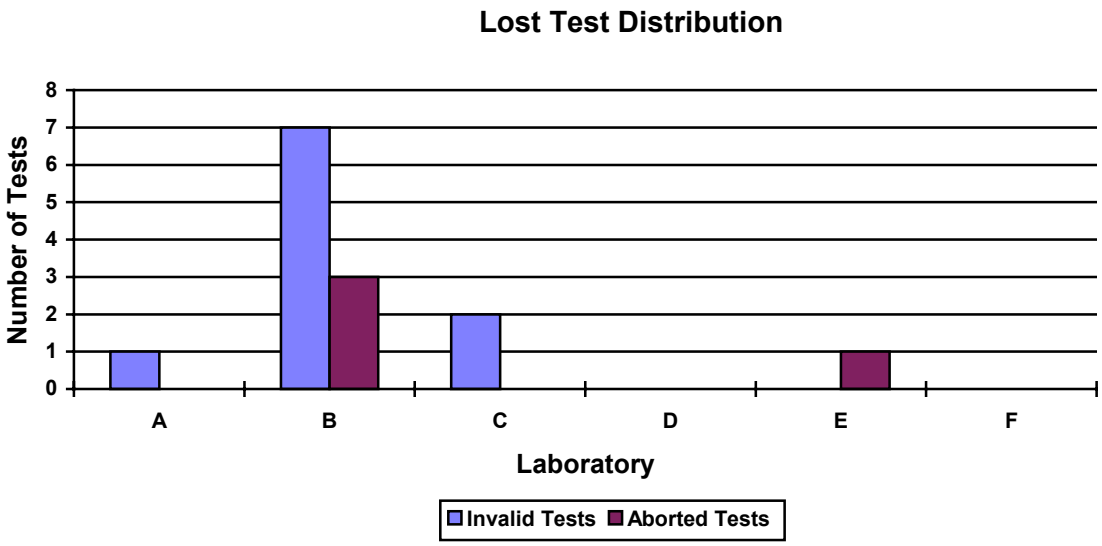
There were no LTMS Deviations this period. There has been one deviation from the LTMS since its introduction in 1999.

There were five QI Deviations written this period. One was written for coolant out temperature problems and four were written for exhaust backpressure control problems.

Lost Test Summary

Fourteen tests were lost this period. The causes are summarized in the following chart:

Lab	Reason for Lost Test	Number of Tests	Breakdown of Tests (LC/RC/XC)
A	Auxiliary Air Control Valve Set Wrong	1	1/0/0
B	Load Control Problems	1	1/0/0
	Oil Cylinder Head Temperature QI Results below zero	1	1/0/0
	Speed & Load Control	1	1/0/0
	Oil Cylinder Head Thermocouple inserted to incorrect depth	2	1/0/1
	Stand Pulled from LTMS	2	2/0/0
	Engine Overspeed on start-ups	1	1/0/0
	Stand Software Problems	1	0/0/1
	Driveline failure	1	0/0/1
C	Coolant Out Temperature, Intake Air Pressure, and Exhaust Backpressure QI Results below zero	1	1/0/0
	MAF Problems	1	1/0/0
E1	Engine Performance Problems	1	0/0/1



Information Letters

Sequence IVA Information Letter No. 00-4, Sequence No. 4, dated January 12, 2001, was issued during the period and contained a requirement that laboratories must successfully run a reference oil test on a camshaft lot before bringing that lot into use in the laboratory.

Severity and Precision Analysis

Below is a summary of the average Δ/s, pooled standard deviation, and average Δ in reported units for the tests reported during this period. Also below is a summary of the average Δ/s value, by parameter, for all laboratories reporting data during this period.

Industry Severity Summary			
Parameter	Average Δ/s	Pooled standard deviation (degrees of freedom)	Average Δ, in micrometers
ACW	0.124	14.74 (df=31)	1.83

ACW Results, by Laboratory	
Laboratory	Average Δ/s
A	-0.245
B	0.952
C	-0.378
D	-
E1	-1.466
F	-1.713

The industry began the period in a precision alarm. Since then, the industry has been in and out of a precision alarm condition for much of the period, finally clearing the alarm for the last 12 data points. Severity, on the other hand, was within limits for much of the period during those precision alarms, with only two data points being beyond the Warning limit. However, when precision returned to within limits, the industry then experienced a severity alarm of six data points in the severe direction. This is different from the previous problems the industry experiences with unexplained mild wear results.

The TMC has been investigating the industry data set in an effort to determine a cause for the erratic wear results seen in the Sequence IVA test. To that end, the data was examined for significant differences in ACW performance due to various factors. The data was examined for differences in fuel batch, camshaft lot, cylinder head lot, rocker arm lot, laboratory, stand, as well as various interactions of these factors. The used oil analysis results for fuel dilution, copper content, and iron content were also examined for effects on ACW performance. A summary of some of the means and standard deviations for these groups of data are shown in the tables below:

Table A – ACW Mean & Standard Deviations, by Fuel Batch

Fuel Batch[1]	N size	Mean	Standard Deviation
0011769	2	108.50	2.22
9701035	8	111.58	13.03
9903160	33	121.72	11.67
9910650	34	122.00	20.46

[1]One data point on a unique fuel batch not shown.

Table B – ACW Mean & Standard Deviations, by Camshaft Lot

Camshaft Lot[2]	N size	Mean	Standard Deviation
971103	14	122.53	11.12
971114	10	117.54	15.21
980929	5	118.98	9.38
981013	11	124.58	14.52
981015	6	118.86	11.74
98928	11	119.07	33.70
990628	8	123.40	12.46
N/A	7	121.70	8.16

[2]Six data points on unique camshaft lots not shown.

Table C – ACW Mean & Standard Deviations, by Cylinder Head Lot

Cylinder Head Lot	N size	Mean	Standard Deviation
960907	2	123.32	2.81
971001	20	118.75	12.75
981030	13	120.85	10.37
N/A	43	121.53	19.80

Table D – ACW Mean & Standard Deviations, by Rocker Arm Lot

Rocker Arm Lot[3]	N size	Mean	Standard Deviation
971001	22	122.29	11.93
981020	33	120.86	21.46
991029	8	123.40	12.45
N/A	12	118.49	11.29

[3]Three data points on unique rocker arm lots not shown.

Table E – ACW Mean & Standard Deviations, by Laboratory			
LTMS Laboratory	N size	Mean	Standard Deviation
A	26	122.91	9.95
B	25	128.67	12.34
C	6	123.86	13.69
E1	12	105.00	25.62
F	9	111.48	12.19

Table F – ACW Mean & Standard Deviations, by Stand			
LTMS Apparatus (LTMS Lab – LTMS Stand)	N size	Mean	Standard Deviation
A-1	8	126.67	9.63
A-2	8	119.50	8.07
A-3	7	118.30	10.33
A-4	3	132.69	6.63
B-1	3	125.78	6.15
B-1A	6	121.70	12.75
B-2	3	128.38	18.60
B-2A	5	131.72	9.29
B-3	6	132.54	15.25
B-3A	2	135.10	5.39
C-1	6	123.86	13.69
E-1	8	98.59	29.34
E1-1	4	117.80	8.41
F-1	9	111.48	12.19

The analysis showed no differences between fuel batches, camshaft lots, head lots, or rocker arm lots at a 95% confidence level. Analyzing the data for interactions between the three hardware categories also showed no significant differences between the various combinations, although the data for this analysis was quite limited since every lab has not run every hardware lot.

An analysis of laboratory differences did show some significant differences amongst some of the laboratories. The results showed that Lab B is significantly different at the 95% confidence level from both Labs E1 and F. Lab A was also found to be different from Lab E1 at the 95% confidence level.

However, the perception in industry is that camshaft lot is a significant factor in the current ACW situation, so this data was examined more closely, along with the laboratory differences mentioned above. In Figure A, all the data in the LTMS data set is plotted by camshaft lot, using different symbols for each laboratory. From this plot, there appears to be very little difference in the ACW performance of the various camshaft lots.

The LTMS data is further shown in Figure B (which has multiple pages), where the ACW results are plotted by laboratory, one camshaft lot per plot. The boxes on Figure B represent the mean and standard deviation of the data for that laboratory on that camshaft lot. Only camshaft lots with data from more than one laboratory are shown in Figure B. As a result, camshaft lots 971103, 971114, 981013, 981015, 98928, and 990628 are shown in Figure B. Several of these plots show a difference in performance for a particular camshaft lot at various laboratories, but the analysis did not show these differences to be significant. No explanation for these differences has been found at this time.

The used oil analysis data was also examined to see if fuel dilution, copper content, or iron content of the used oil samples was any indicator of wear performance. The first two, fuel dilution and copper content, were not found to be useful indicators of ACW performance in the Sequence IVA test. Iron

content, as expected, was a significant indicator of wear performance, but beyond that did not yield any useful information.

To date, no explanation for the wear anomalies have been found at this time. There may be a laboratory and hardware interaction resulting in differing levels of severity on the same hardware, but no explanation for the cause of this interaction has been found at this time.

Along these same lines, the issue of test target updates has been an item of interest to the Surveillance Panel. The targets were due to be updated a while ago, but were not updated due to the precision alarms experienced by the industry. Chairman Bendele asked the TMC to prepare some possible target revisions based upon the LTMS data for consideration by the panel at the next meeting of the panel. Some possible targets, along with the current test targets, are shown in Table G, below:

Table G – Reference Oil 1006 Test Targets

Description	Mean	Standard Deviation	Effective Dates, if any
All Data	120.75	16.50	None
All Data, lab pooled standard deviation	120.75	14.56	None
Data Screened for Rare Events (1 found)	121.76	13.97	None
Rare Event Screened and lab pooled s	121.76	12.50	None
Original Targets	117.14	12.23	19991001 to 20000125
Current Targets	121.38	9.86	20000126 to present

No severity adjustments were applied to the data in generating the first two sets of targets shown in Table G. The first set of targets is a simple mean and standard deviation calculated from the data set. The second set of targets in Table G contains a standard deviation which was pooled across all laboratories, attempting to factor out any laboratory variations from the results obtained in the calculation. In both cases, the target means are very close to the current target while the standard deviation is significantly larger than the current or original target standard deviation. Industry control charts based upon these two sets of targets and the existing LTMS data set are shown in Figures C and D respectively. As expected, these targets reduce or eliminate the alarms currently shown in Figure 1.

There was also some discussion of using statistical outlier tests to remove the outlier data from the LTMS data set and then generate test targets from the resultant data set. From Table 1 of Standard Practice E178, the critical value for T for an upper 2.5% significance level (equivalent to a 5% significance level on a two-sided test) is found to be 3.297, meaning tests beyond 3.297 standard deviations from the mean can be excluded as rare events. Screening the LTMS data using this criteria results in one data point being excluded from the calculation. The third and fourth set of targets in the table are based on this new, reduced data set and were calculated in the same manner as the previous two sets of targets. As you can see, it had little effect on the results of the calculation. As a result, control charts using either of these two sets of test targets would fall somewhere between the current control chart and those shown in Figures C and D.

Reintroduction of reference oil 1007 was also a topic for discussion at the last meeting and the TMC was tasked with examining the available data on that oil and suggesting some possible test targets for that oil of the panel decides to reintroduce it into the LTMS. Those proposals were issued to the Surveillance Panel in TMC Memorandum 01-004, issued on January 9, 2001.

Hardware

No hardware changes were made this period.

Reference Oils

Oil	TMC Inventory, in gallons	TMC Inventory, in tests	Laboratory Inventory, in tests	Estimated life
1006	498	124	28	3+ years[1]
1007[2]	619	154	9	3+ years[1]

[1] Multiple test area reference oil; total TMC inventory shown
2 Cannot be reblended

MTK/mtk

Attachments

c: F. M. Farber, TMC
Sequence IVA Surveillance Panel
ftp://tmc.astm.cmri.cmu.edu/docs/gas/sequenceiv/semiannualreports/IVA-04-2001.pdf

List of Figures

- Figure 1 graphically presents the Industry control charts for ACW and also the CUSUM delta/s plot (by count in completion date order) of average camshaft wear for operationally valid tests.

- Figure 2 graphically presents a historic perspective for ACW mean delta/s by report period.

- Figure 3 graphically presents a historic perspective for ACW pooled standard deviations by report period.

- Figure 4 is the Sequence IVA Timeline, created to track changes in test hardware and operations.

The following tables and figures refer to the Severity and Precision Analysis section of this report:

- Table A contains the N size, mean, and standard deviation of the ACW results for all data in the LTMS Data set, calculated by fuel batch.
- Table B contains the N size, mean, and standard deviation of the ACW results for all data in the LTMS Data set, calculated by camshaft lot number.
- Table C contains the N size, mean, and standard deviation of the ACW results for all data in the LTMS Data set, calculated by head lot number.
- Table D contains the N size, mean, and standard deviation of the ACW results for all data in the LTMS Data set, calculated by rocker arm lot number.
- Table E contains the N size, mean, and standard deviation of the ACW results for all data in the LTMS Data set, calculated by LTMS laboratory code.
- Table F contains the N size, mean, and standard deviation of the ACW results for all data in the LTMS Data set, calculated by LTMS laboratory and stand code.
- Table G contains two possible sets of test targets based on the current LTMS data set as well as the current and original test targets used for reference oil 1006 in the Sequence IVA test.
- Figure A shows all LTMS data, plotted by camshaft lot number, using different symbols for each laboratory.
- Figure B (6 plots total) shows individual test results, plotted by laboratory, with one camshaft lot per plot. Also shown on the plot are boxes, which represent the mean and standard deviation (plotted as the mean plus and minus one standard deviation), for that lab's data on that hardware. Only camshaft lots with runs from more than one lab are shown.
- Figure C is the industry control chart, plotted using the first set of targets in Table G.
- Figure D is the industry control chart, plotted using the second set of targets in Table G.

SEQUENCE IVA INDUSTRY OPERATIONALLY VALID DATA

AVERAGE CAM WEAR

Figure 1

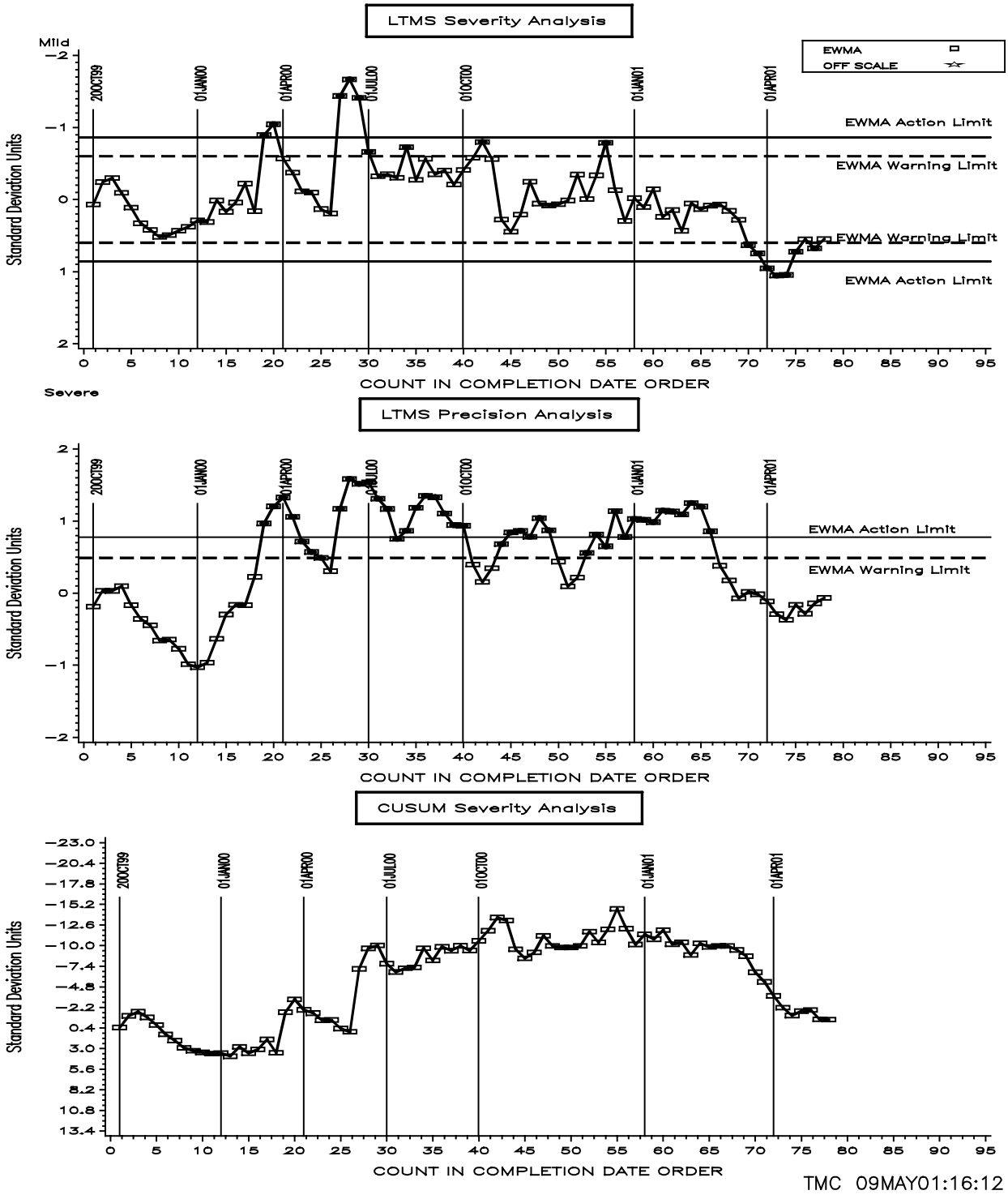


Figure 2 - Sequence IVA Reference Oil Data
Average Camshaft Wear

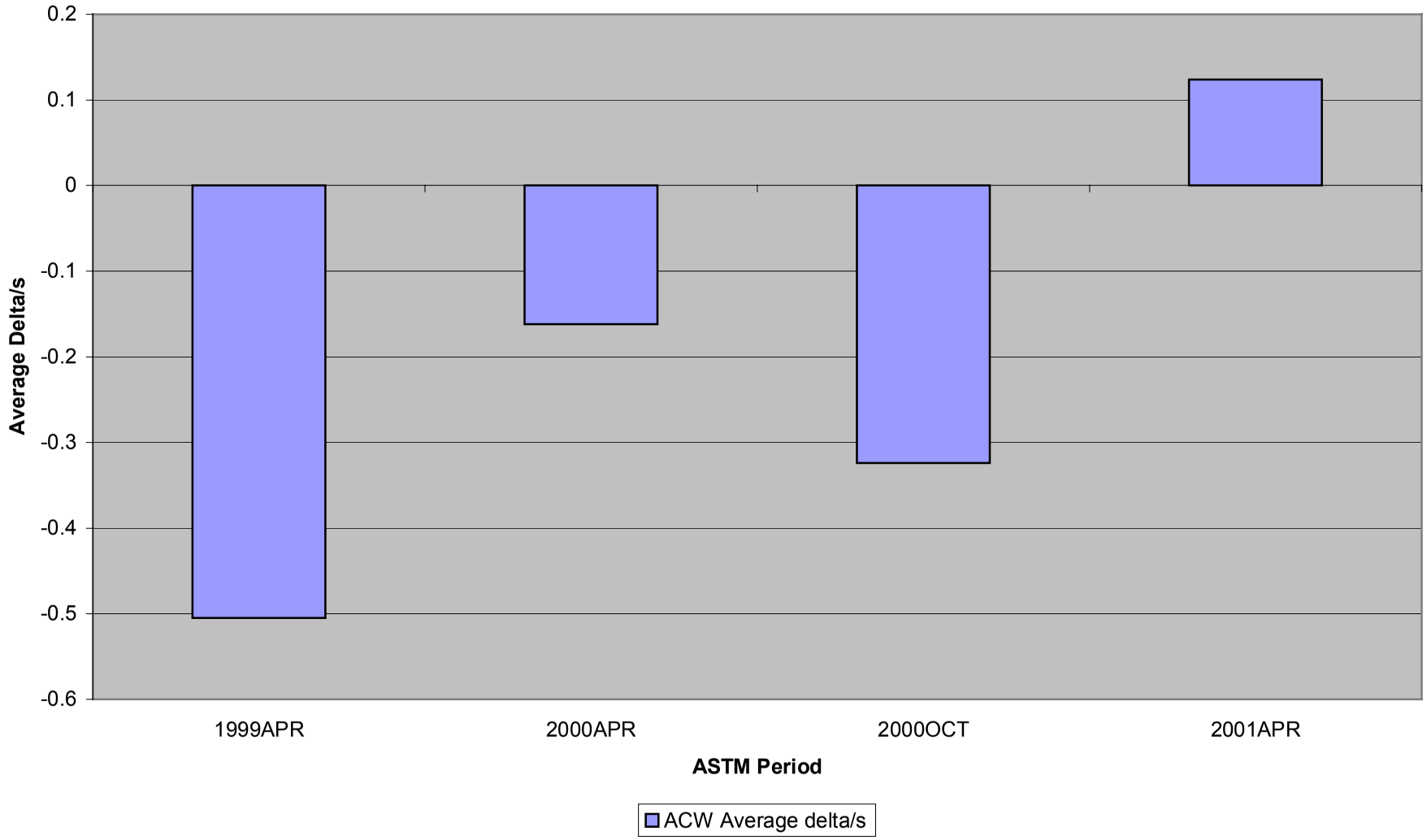


Figure 3 - Sequence IVA Reference Oil Data
Average Camshaft Wear

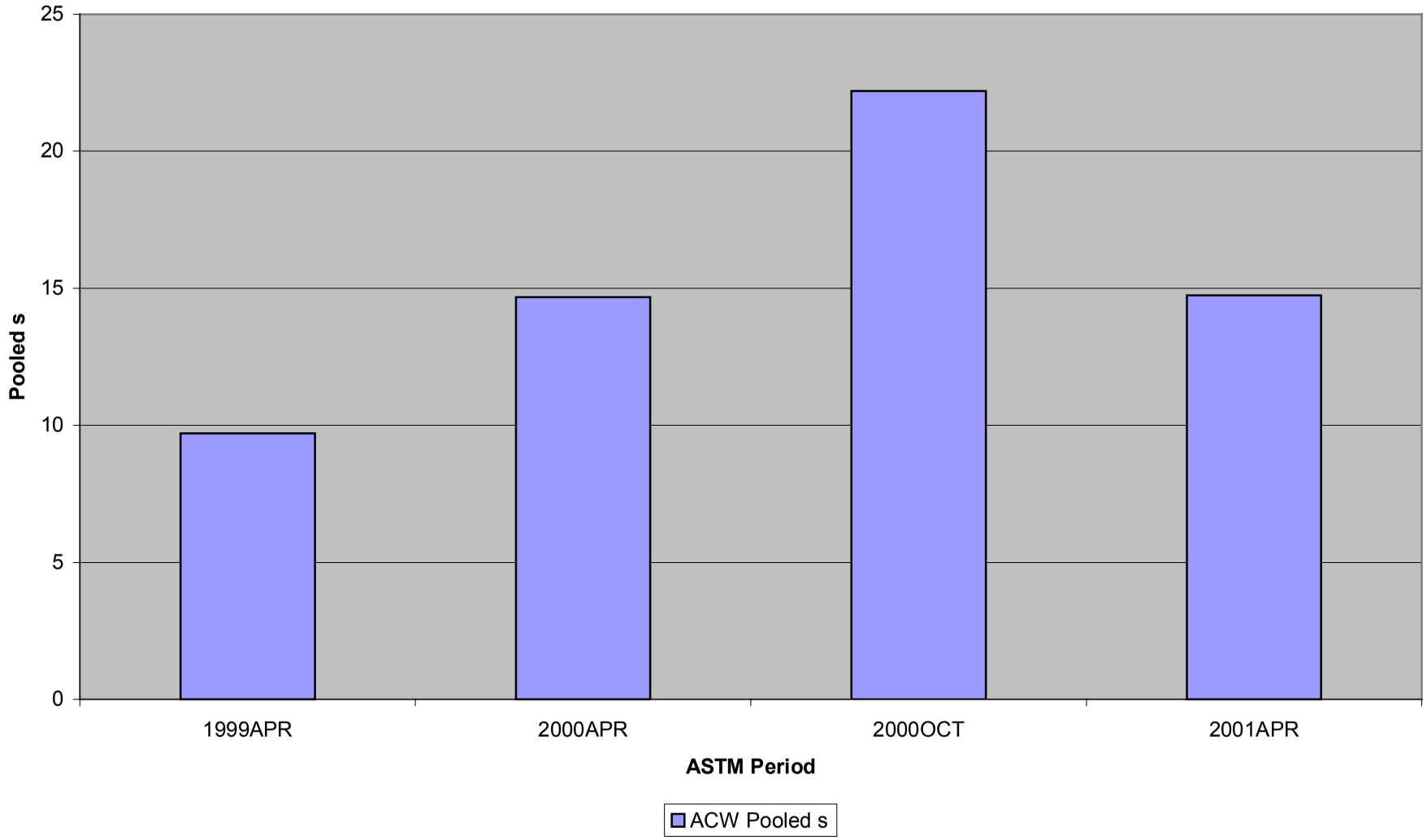


Figure 4 - Sequence IVA Timeline		
Date	**Topic**	**Information Letter**
2/10/1999	SEQUENCE IVA TEST LTMS ESTABLISHED BY SURVEILLANCE PANEL	
11/17/1999	CALIBRATION STATUS RESUMED	
2/16/2000	DRAFT 4 OF TEST PROCEDURE ISSUED. INCORPORATED JACKETED ROCKER COVER, CONTROLLED FLOW OF FRESH AIR TO ROCKER COVER, AND OIL CYLINDER HEAD AS OIL TEMPERATURE CONTROL POINT.	00-1
8/1/2000	REVISED DATA DICTIONARY AND REPORT FORM SET (VERSION 20000126) GOES INTO EFFECT.	00-2
6/12/2000	REVSED DOUBLE-FLUSH COOLANT CONTROL REQUIREMENTS EFFECTIVE	00-3
6/12/2000	REVISED ENGINE STARTING PROCEDURE EFFECTIVE	00-3
6/12/2000	ELIMINATE THE REQUIREMENT FOR LINEAR RAMPING OF TRANSIENT PARAMETERS	00-3
6/12/2000	REVISED OIL SAMPLING PROCEDURE	00-3
6/12/2000	REVISED DOUBLE-FLUSH OIL DRAIN REQUIREMENT	00-3
6/12/2000	REVISED COMPRESSION TEST REQUIREMENTS	00-3
6/12/2000	NEW CAMSHAFT CLEANING REQUIREMENTS	00-3
1/24/2001	CAMSHAFT LOT RESTRICTIONS	00-4

Figure A

Sequence IVA Reference Oil Data

Individual Lab Data, Plotted By Camshaft Lot

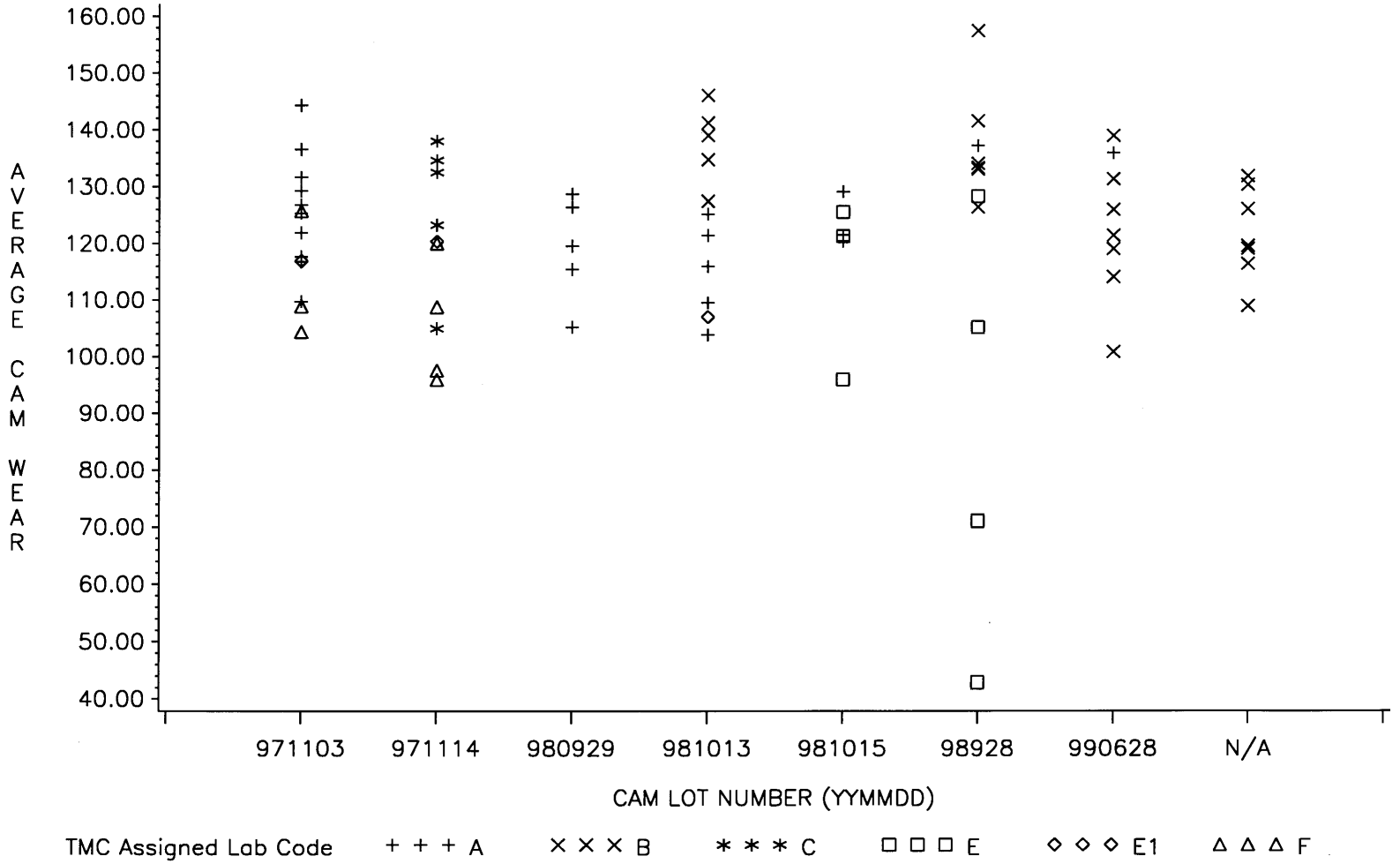


Figure B

Sequence IVA Reference Oil Data

Individual Camshaft Lot Data, Plotted By Laboratory

CAM LOT NUMBER (YYMMDD)=971103

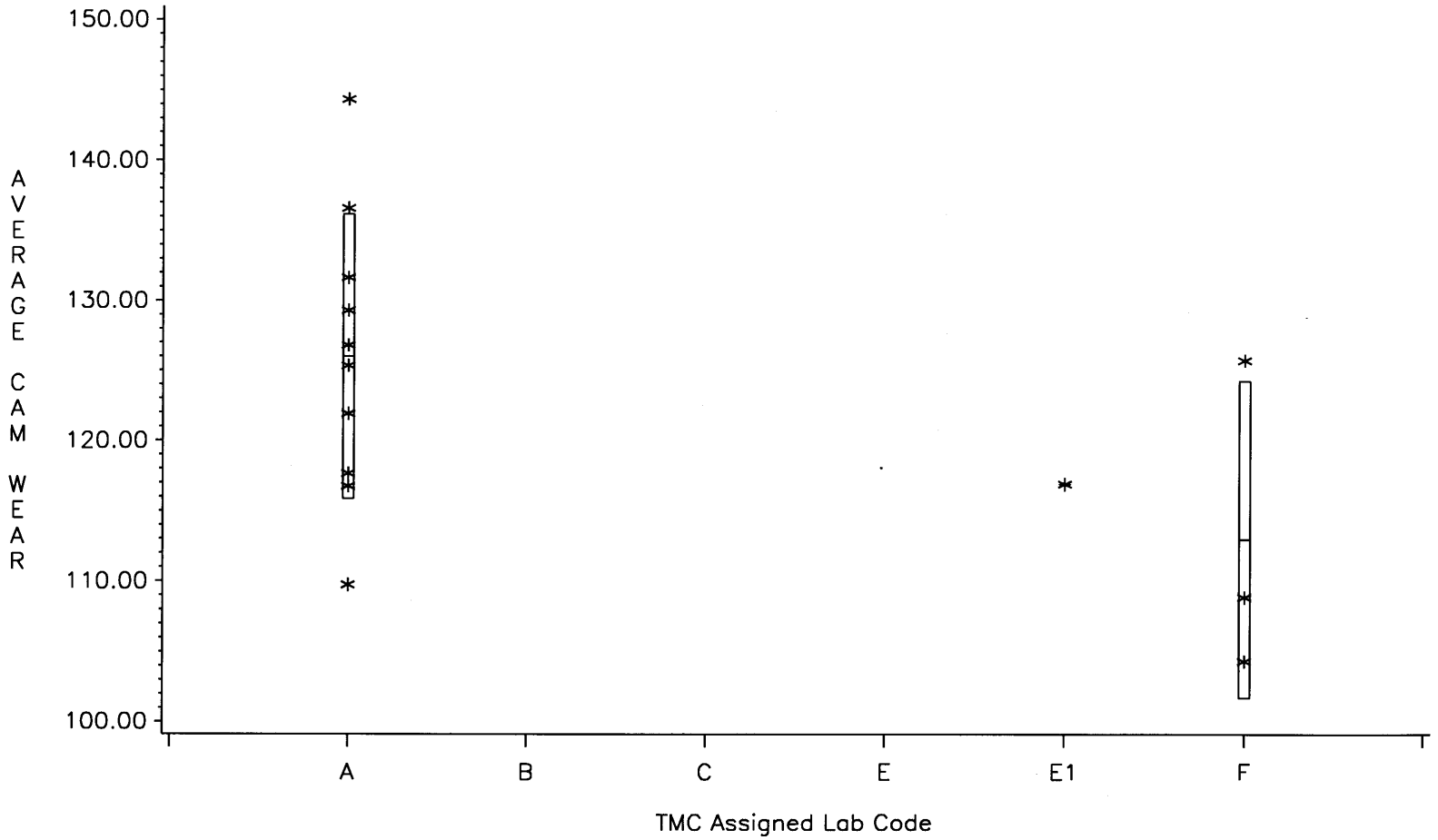


Figure B

Sequence IVA Reference Oil Data

Individual Camshaft Lot Data, Plotted By Laboratory

CAM LOT NUMBER (YYMMDD)=971114

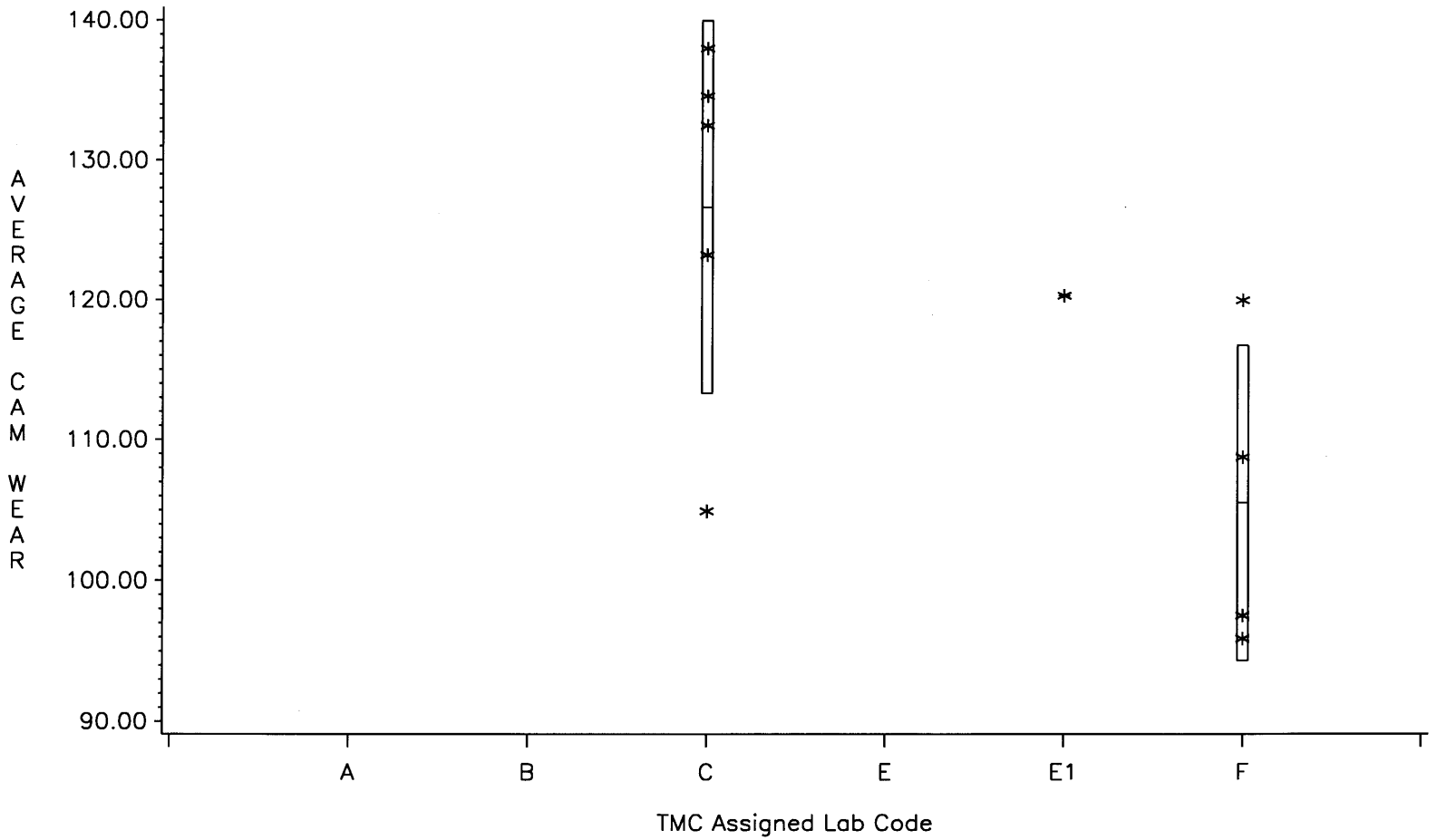


Figure B

Sequence IVA Reference Oil Data

Individual Camshaft Lot Data, Plotted By Laboratory

CAM LOT NUMBER (YYMMDD)=981013

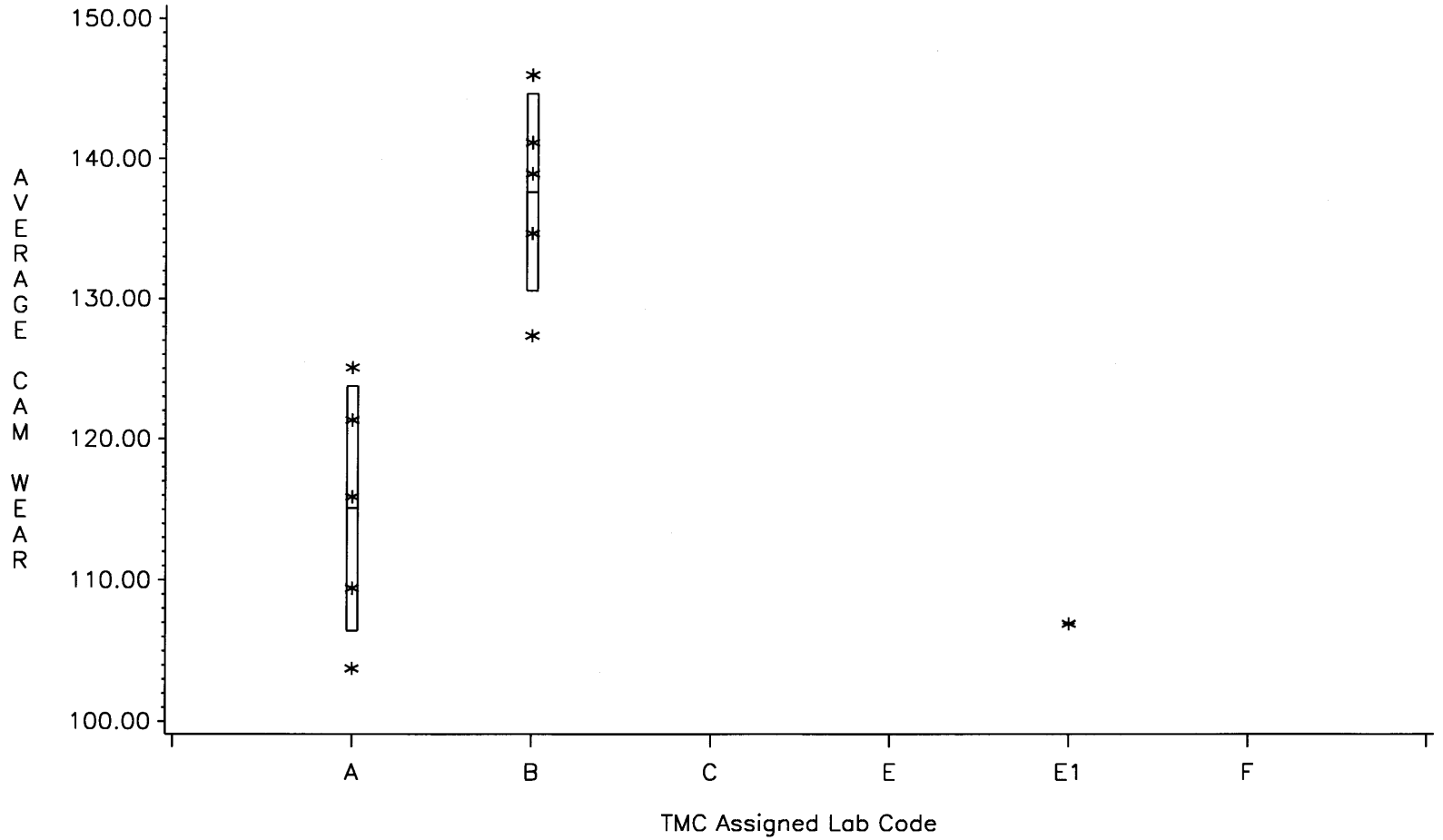


Figure B

Sequence IVA Reference Oil Data

Individual Camshaft Lot Data, Plotted By Laboratory

CAM LOT NUMBER (YYMMDD)=981015

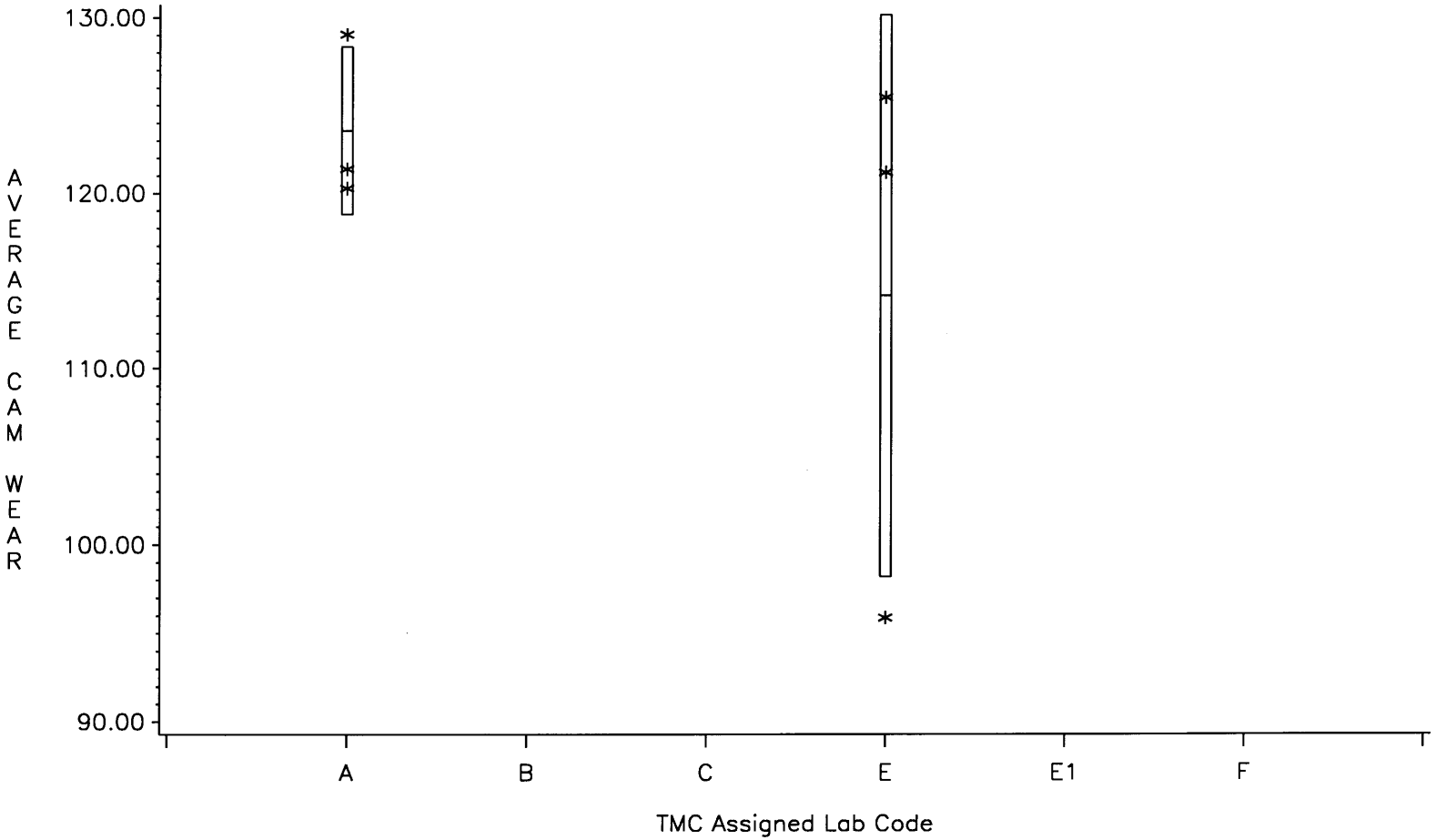


Figure B

Sequence IVA Reference Oil Data

Individual Camshaft Lot Data, Plotted By Laboratory

CAM LOT NUMBER (YYMMDD)=98928

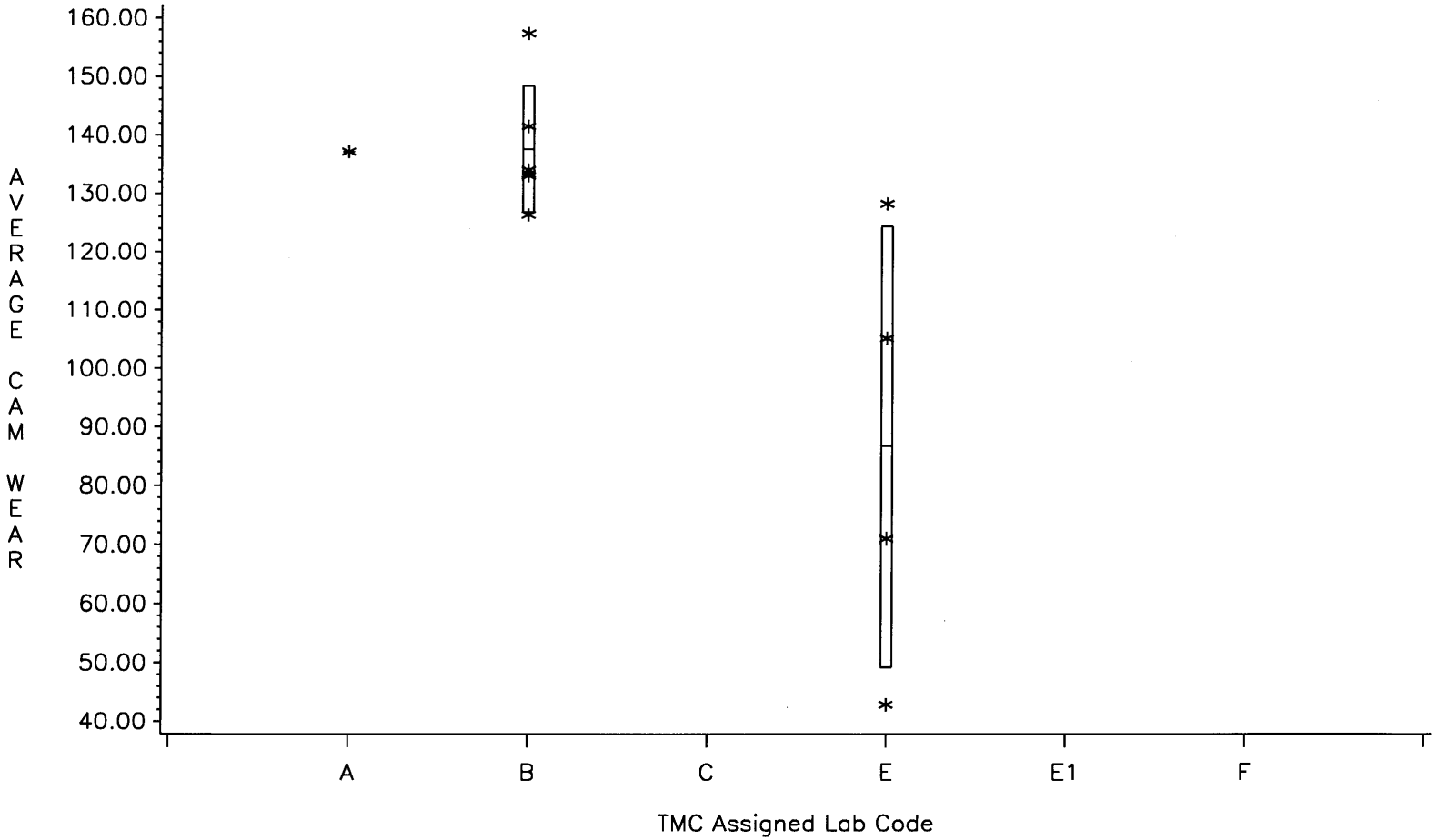
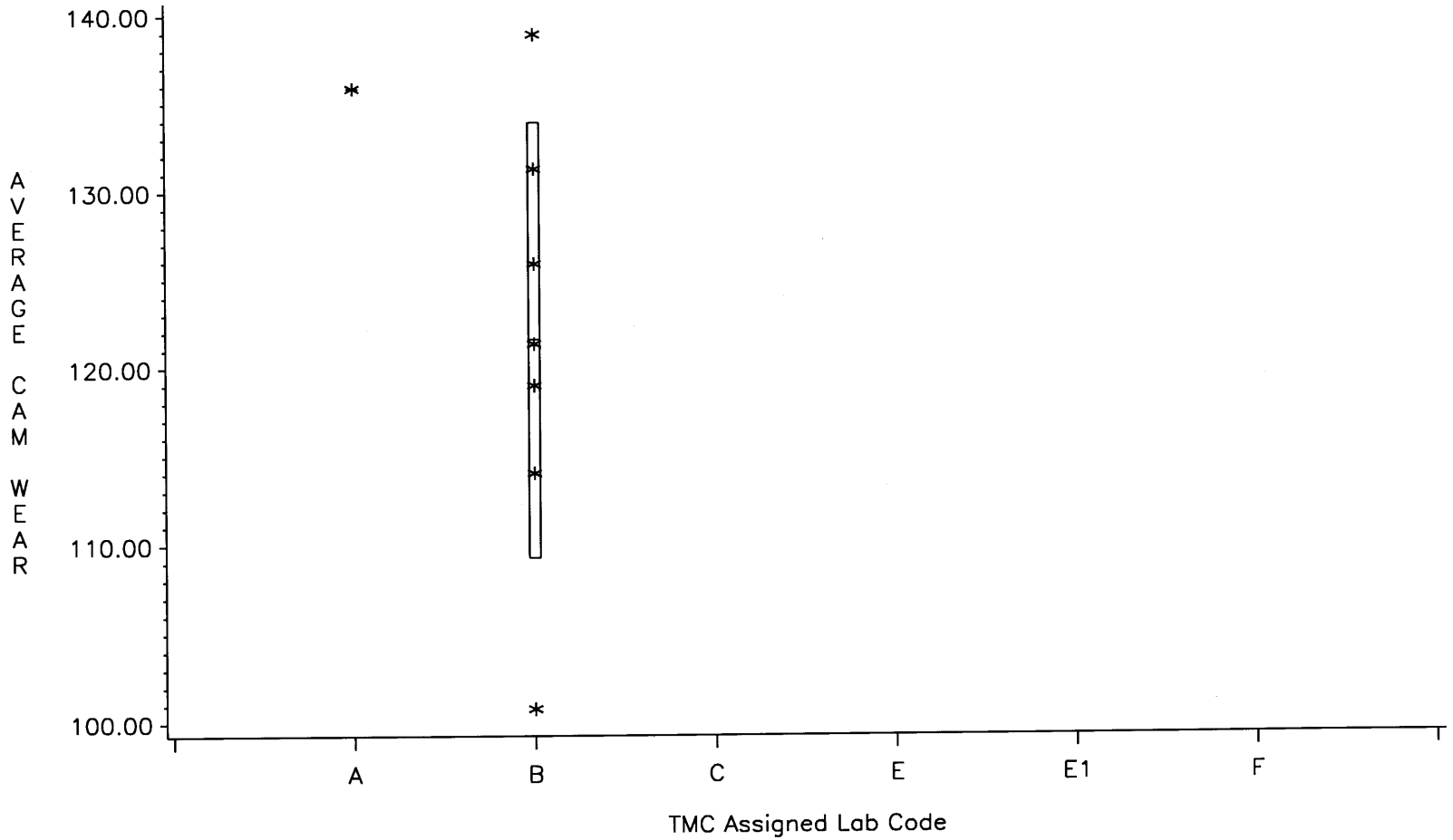


Figure B

Sequence IVA Reference Oil Data

Individual Camshaft Lot Data, Plotted By Laboratory

CAM LOT NUMBER (YYMMDD)=990628

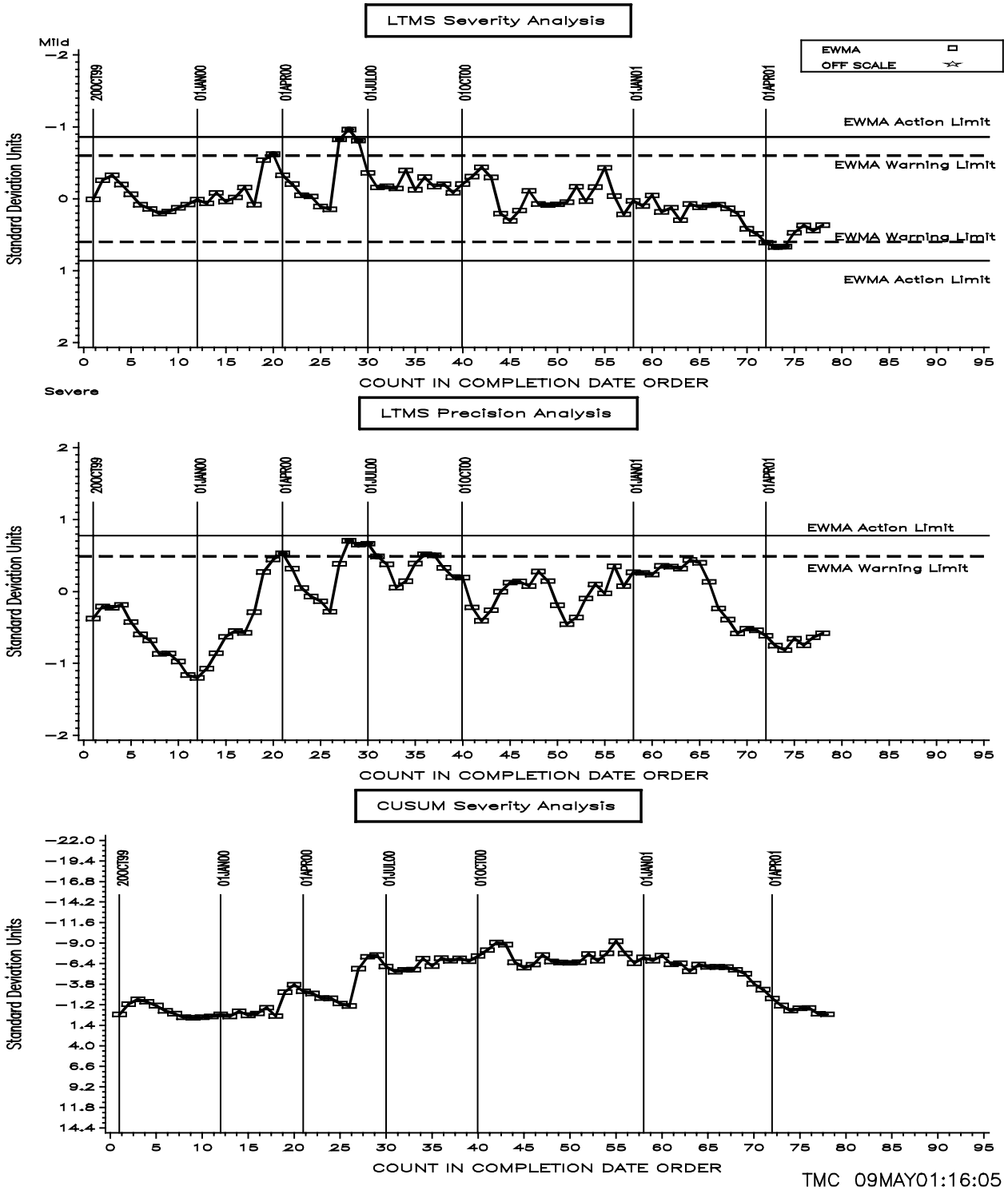


SEQUENCE IVA INDUSTRY OPERATIONALLY VALID DATA

Plot using new mean and 16.50 standard deviation

AVERAGE CAM WEAR

Figure C



TMC 09MAY01:16:05

SEQUENCE IVA INDUSTRY OPERATIONALLY VALID DATA

Plot using new mean and 14.56 standard deviation

AVERAGE CAM WEAR

Figure D