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MEMORANDUM: 05-005

DATE: January 20, 2005

TO: Sequence III Surveillance Panel

FROM: Michael T. Kasimirsky

SUBJECT: An Analysis of Current Sequence IIIG Severity Trends

A review of the latest industry control charts (see attached) shows changes in the mild direction on Percent Viscosity Increase (PVIS) and in the severe direction on Weighted Piston Deposits (WPD). There is also the perception in industry that WPD performance on candidate oils has been shifted in the severe direction, even though the latest RSI report shows PVIS and WPD to be on-target and Average Camshaft-plus-Lifter wear (ACLW) to be shifted severe.

The reference oil data was reviewed for significant differences in PVIS and WPD performance, as well as wear metal (iron, copper, and lead) results from each 20-hour sample, associated with hardware batch changes, the honing change, laboratory, and others. Several significant differences were found.

One difference happened to be piston ring batch. Ring batches 3 and 4 were found to be different on PVIS performance and ring batches 3 and 3A were different than batch 4 on WPD severity. *However*, the data also showed that rocker arm batches 6 and 8 were different on PVIS performance and that PE pour code camshafts were different on WPD performance than both NF and PK pour code camshafts. There is no physical evidence to support that rocker arm batches have any effect on PVIS performance, nor is there evidence to support that camshaft pour codes play a role in WPD severity. What these factors all share is a common time factor: the latest results are different than the earlier results. As such, there is little evidence to support that hardware changes played any role in the changes seen on the industry control charts, with one exception, which will be addressed in a moment.

A review of the effects of the new honing technique on test performance showed quite a few differences in test results. Test PVIS performance as well as almost all the wear metals results were significantly different due to the change in honing technique. Point A on the PVIS control chart shows the point at which the industry made an across-the-board switch to the new honing technique. There are a few data points utilizing the new honing technique before this point, but they are interspersed with data using the old honing technique. The data clearly shows a mild shift that is coincident with the introduction of the new honing technique. In addition, the honing technique also resulted in a significant difference in oil consumption performance in the Sequence IIIG test. The stated intent of the new honing technique was to reduce oil consumption and it did exactly what was intended. It is also known that a reduction in oil consumption is very likely to result in a reduction in PVIS severity and the industry CUSUM control chart clearly shows a change in PVIS performance. In addition, significant differences in the wear metals were found on iron (40, 60, 80, and 100 hour samples), copper (20, 40, 60, 80, and 100 hour samples), and lead (20, 40, 60, and 80 hour samples) due to the change in honing technique. Averages of all three wear metals in the samples mentioned above were found to be lower with the new honing technique. Both iron and copper are known to drive viscosity increase to some extent, depending on oil chemistry. In the Sequence IIIE test, iron content was known to affect the viscosity performance of the discrimination oils, 403 and 476-4, and the effect of copper on oil viscosity performance is known well enough that the Test Developer has explicitly prohibited cuprous oil lines and fittings in the Sequence III tests (IIIE, IIIF, and IIIG at minimum) for some time.

But the introduction of the honing technique does not explain the most recent changes in the PVIS and WPD control charts. The charts were examined and, lacking a better starting point, a point on the chart was chosen by eye to determine when the most recent severity shift began. This point is labeled as point B on the PVIS chart and C on the WPD chart.

Given this starting point, individual data points were reviewed for any common factors. What was found was surprising. This is the exact point in time when the powdered metal (PM) rods began to show up in the reference oil data. The changes to the Sequence IIIG LTMS have resulted in less reference oil testing overall in industry. As a result, there is a limited amount of PM rod data, which helps explain why the data does not show statistically significant differences in performance. However, the data clearly lines up with the PM rod introduction; even to the point that the severe data point (the "sawtooth" point at the 01 OCT 04 date line on the PVIS chart) near point B is a test using the cast connecting rods.

How did the PM rods affect the PVIS performance of the test? When there was a viscosity increase problem in the Sequence IIIE test, it was eventually traced back to a torquing problem on the main bearing caps. The caps were being overtorqued, resulting in the bores becoming triangular and eliminating the clearance between the crankshaft and the main bearings. This resulted in increased PVIS severity. Given the changes in materials and manufacturing techniques, it is reasonable to assume that the new PM rods do not deform in exactly the same way as the old cast rods, resulting in a change in clearance and consequently a reduction in PVIS severity. There is also a new torquing procedure for these connecting rods, which differs from the one for the cast rods, so it is easy to believe that the new material does not behave in exactly the same way as the original cast material.

But how does this explain the shift in WPD performance? In further attempting to understand the severity shifts, discussions with various laboratory engineers have indicated that when operational deviations have resulted in more mild viscosity increase results, weighted piston deposits tended to be more severe. A review of the operationally valid reference oil data does not necessarily support this contention.

However, a review of the WPD control chart shows three data points that do not fit the current severe trend in industry. These points are labeled points D, E, and F on the chart. Point D was a failing test at Lab A and was the second consecutive failing test on Stand 4. The test used PM rods and was run on oil 438. While it did not match the current industry trends, it did seem to conform to the inverse PVIS/WPD relationship in that it generated Yi results of 0.74 on PVIS (severe) and 3.75 on WPD (mild). The next test in the industry control charts was the rerun on this stand and it passed, returning the stand to calibration. It is also of note that these two failing tests (point D and the previous failing result, three tests prior) are the first occurrences of the PM rods in the reference oil data. Point E was a failing result at Lab F on reference oil 438 and was run using cast rods. This test generated Yi results of -3.25 on PVIS (mild) and 4.45 on WPD (mild). However, it was also the second of three failing tests from Lab F on Stand 1 and those three failing results required the laboratory to run two tests to return the stand to calibration, which has been successfully completed. As such, it may be indicative of an isolated problem at the laboratory and not an indication of an overall industry problem. The remaining point, point F, was a passing test on reference oil 438, using PM rods, which was also run at Lab F on Stand 1. It is the first of the two passing tests run by that laboratory to return Stand 1 to calibration. This test generated Yi results of -1.29 on PVIS (mild) and 1.96 on WPD (mild). While this point also did not fit the inverse relationship between PVIS and WPD results, this may be more indicative of a laboratory issue and not overall industry performance. Further evidence of this contention is that Lab F is significantly different than Lab G on WPD performance.

Based upon the data using PM rods (which also incorporates the new honing technique), the current industry shift is quantified in the following table:

Average Δ/s Average Δ[1]	Oil 434 (N=4)	Oil 435 (N=4)	Oil 438 (N=4)	Overall (N=12)
PVIS (transformed units) (s=0.253)[2]	-0.755 -0.191	-0.940 -0.238	-0.652 -0.165	-0.782 -0.198
WPD (merits) (s=0.793)[2]	-1.440 -1.142	-0.364 -0.289	0.936 0.742	-0.289 -0.230

[1] Average Δ calculated from Average Δ/s in table and test precision estimate, s, shown under each parameter.
[2] The precision estimate was taken from the most recent Sequence IIIG Semiannual Report.

At this time, two laboratories are mild on PVIS and have severity adjustments of 0.239315 and 0.201224. As you know, PVIS severity adjustments are applied to transformed PVIS results, making them comparable to the average delta data shown in the table above. On WPD, two laboratories are severe and have severity adjustments of 0.4416 and 0.5369, while one laboratory is mild and has a severity adjustment of -0.4686.

Given that both the PM rods and the new honing technique are here to stay, a consideration of correction factors on both PVIS and WPD are warranted. The most logical choice is to use the data using PM rods (which would also incorporate the new honing technique) and correlate that data with the data prior to January 1, 2004 that did not use the new honing technique. But the specifics of what data to use and what type of correction factor to consider will require further discussion.

MTK/mtk

Attachments

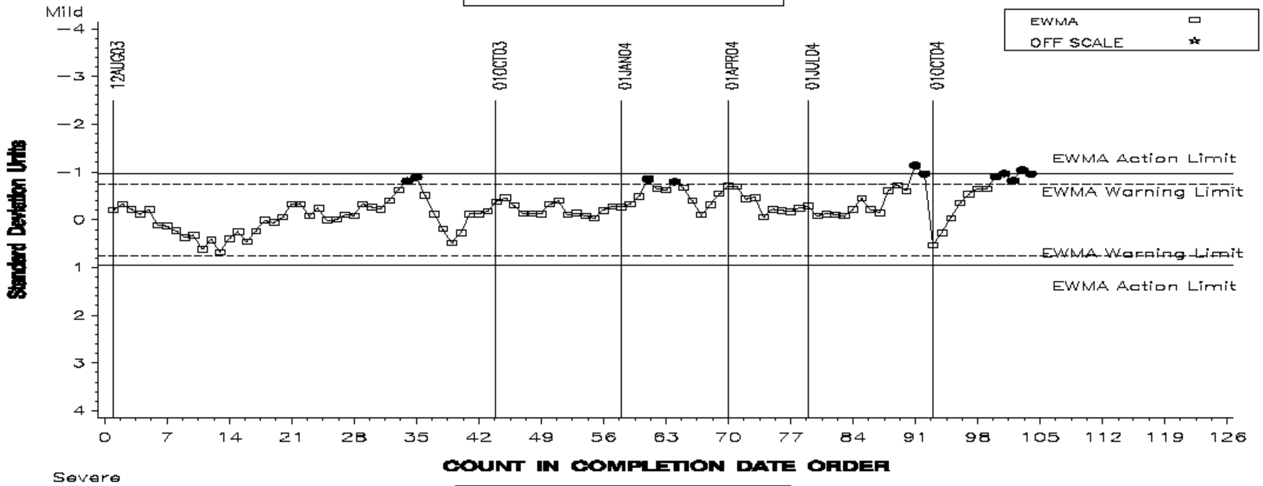
c: ftp://ftp.astmtmc.cmu.edu/docs/gas/sequenceiii/memos/mem05-005.pdf

Distribution: Electronic Mail

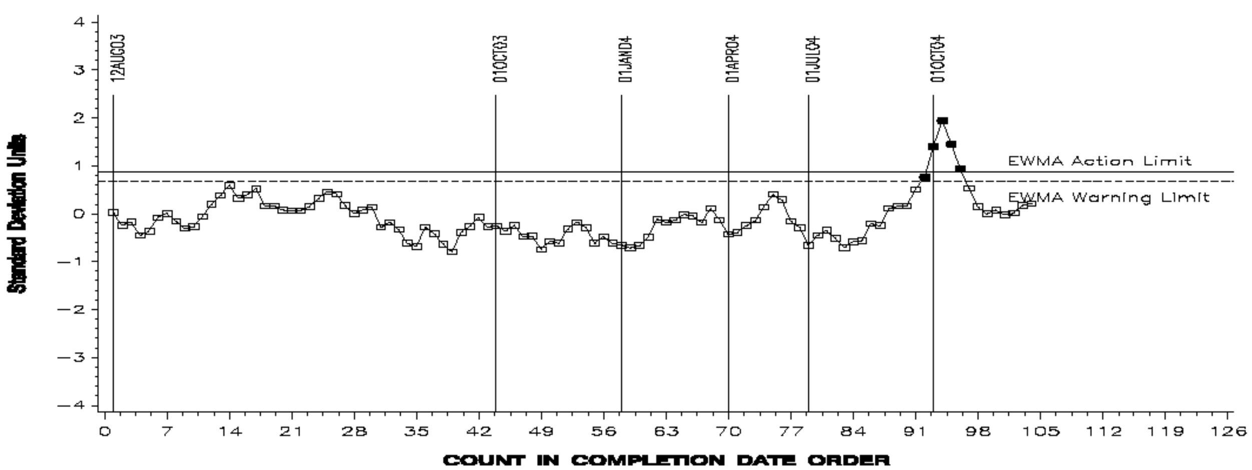
SEQUENCE IIIG INDUSTRY OPERATIONALLY VALID DATA

VISCOSITY INCREASE

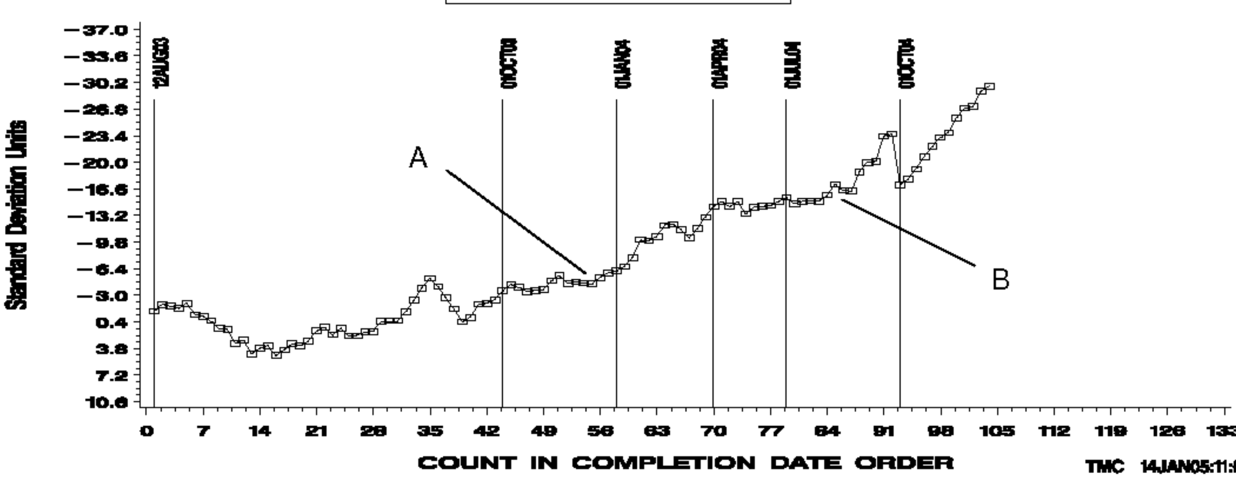
LTMS Severity Analysis



LTMS Precision Analysis



CUSUM Severity Analysis



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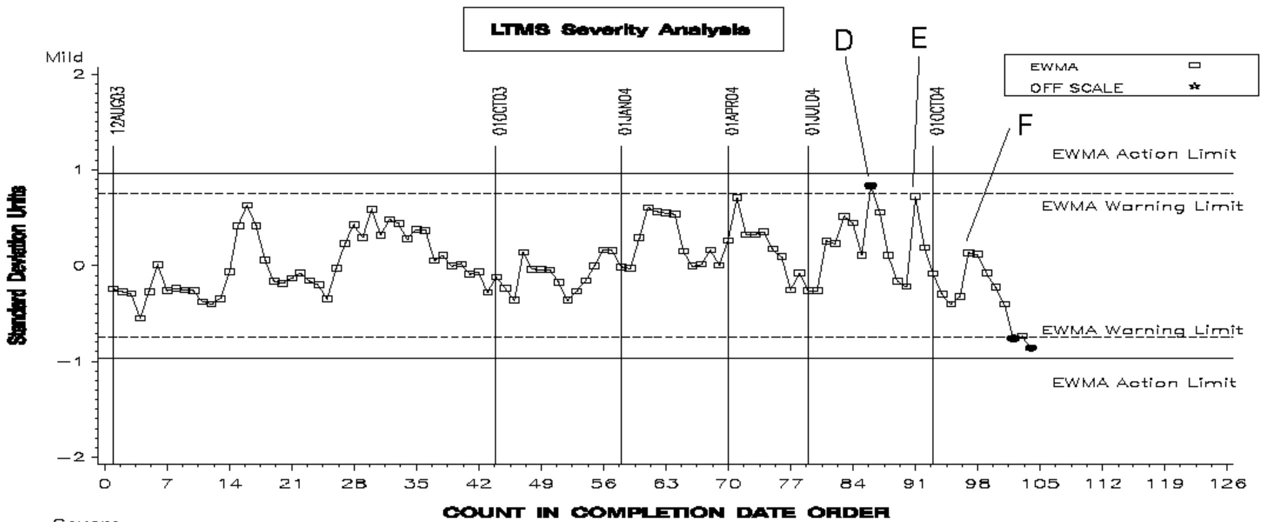
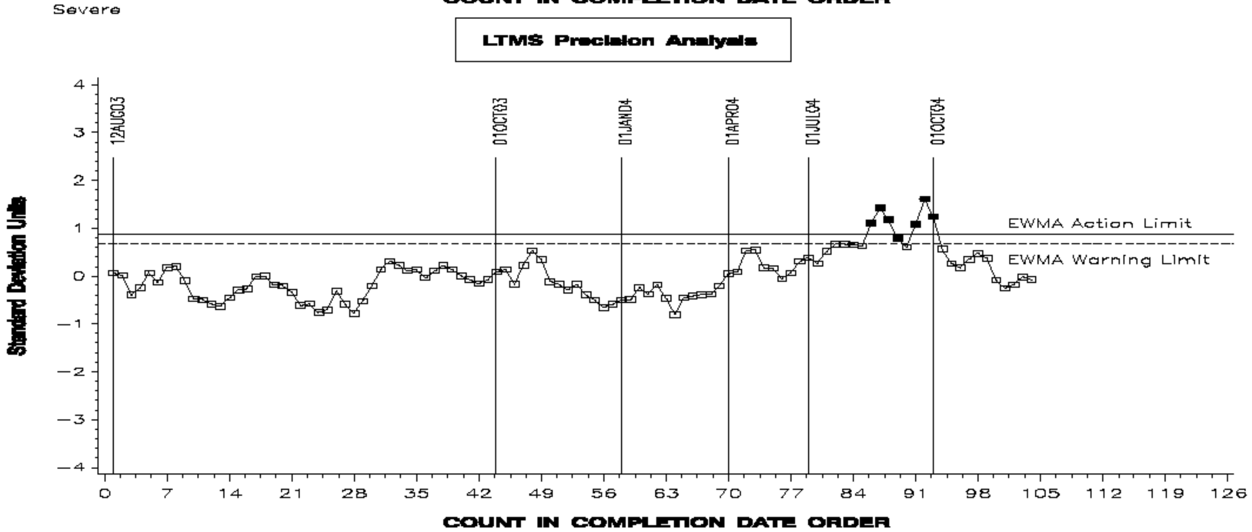
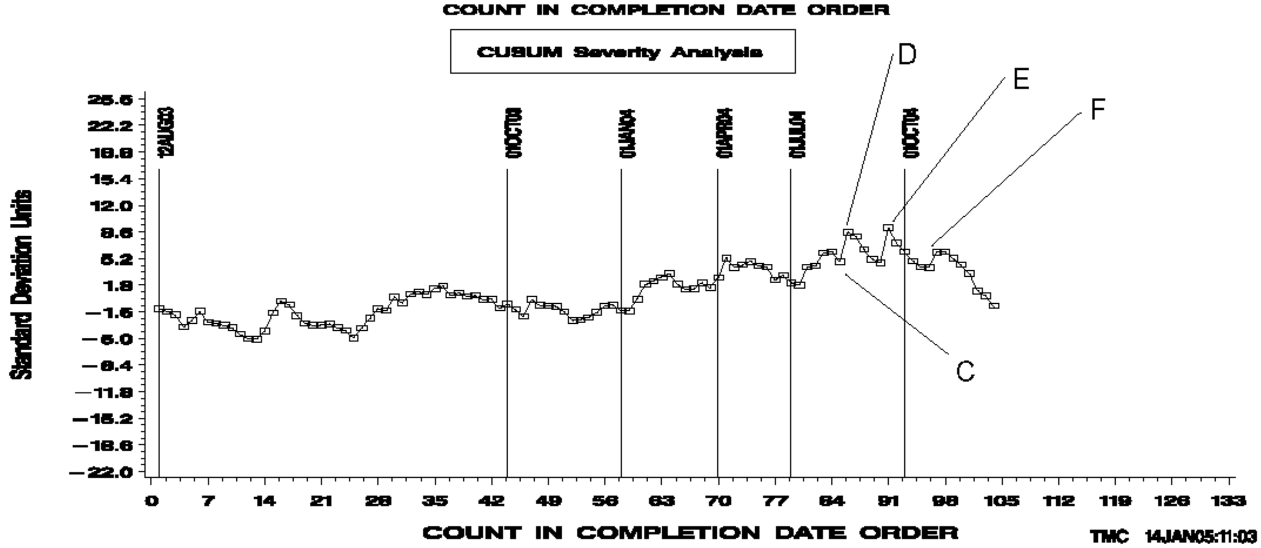
SEQUENCE IIIG INDUSTRY OPERATIONALLY VALID DATA

AVERAGE WEIGHTED PISTON DEPOSITS







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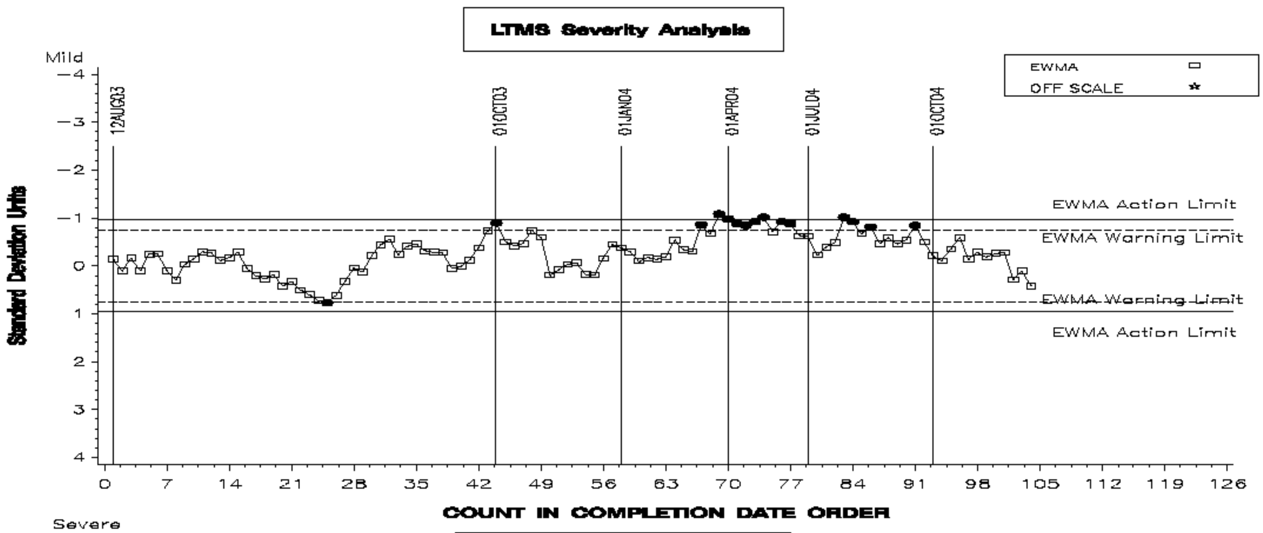
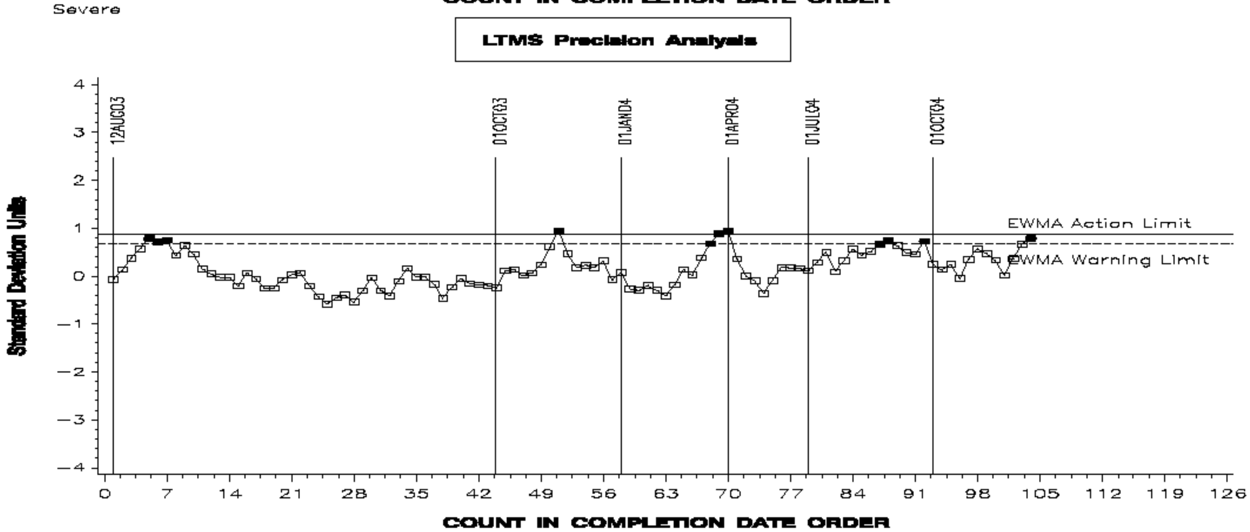
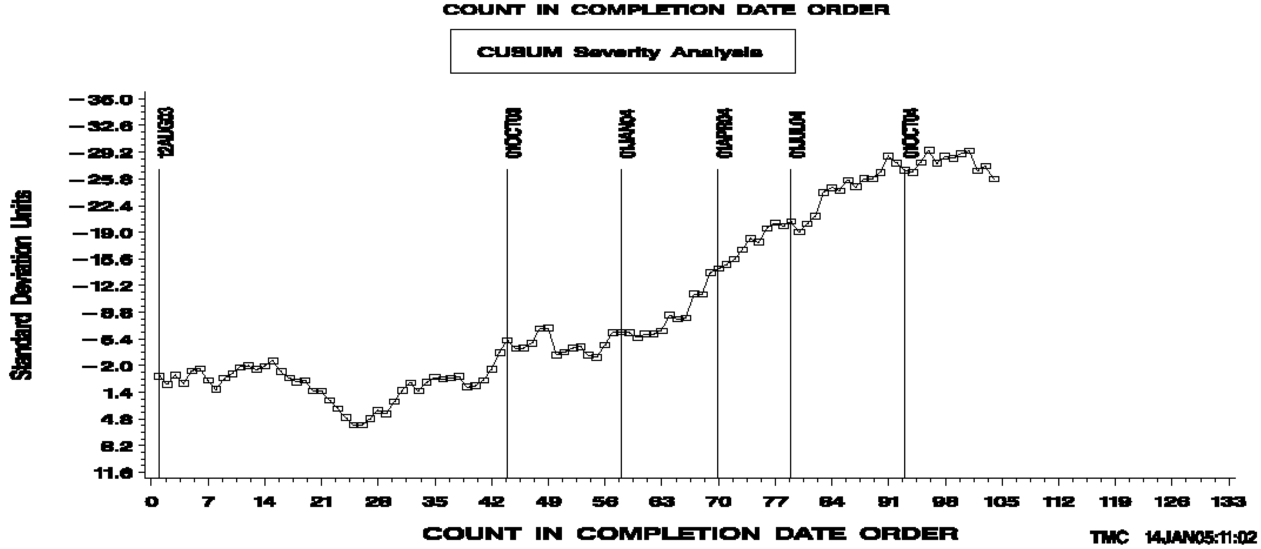
SEQUENCE IIIG INDUSTRY OPERATIONALLY VALID DATA

AVERAGE CAM + LIFTER WEAR







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